# TECHNOLOGY QUARTERLY

AND

## PROCEEDINGS OF THE SOCIETY OF ARTS.

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## *PROCEEDINGS OF THE SOCIETY OF ARTS.*

*THIRTY-FIRST YEAR, 1892–93.*

THURSDAY, April 13, 1893.

THE 445th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. George W. Blodgett in the chair.

The records of the previous meeting were read and approved. Mr. David J. Cartwright, of Boston, was duly elected an Associate Member of the Society. The Chairman then introduced Captain William Brophy, of Boston, who read a paper on the "Fire Hazards of Electricity." At its close the Chairman introduced Mr. H. S. Parshall, of the General Electric Co., who read a short paper on the same subject from the point of view of the producer of electricity. The papers are published in the present number of the *Quarterly*. An interesting discussion followed, after which the thanks of the Society were extended to Captain Brophy and Mr. Parshall, and the meeting adjourned.

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THURSDAY, April 27, 1893.

The 446th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M.

The records of the previous meeting were read and approved.

The President was authorized to appoint a committee of five to nominate officers for the ensuing year. Prof. C. R. Cross, of the Insti-

tute, then gave an "Account of Some Recent Investigations in Acoustics Made in the Rogers Library of Physics." At its close the meeting adjourned.

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THURSDAY, May 11, 1893.

The 447th and annual meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. Henry M. Howe in the chair.

The records of the previous meeting were read and approved. The Nominating Committee reported for reëlection the names of the officers of the past year, and they were duly chosen for the ensuing year.

The reports of the Executive Committee and of the Permanent Meteorological Committee were read, accepted, and ordered to be placed upon the records. Mr. Desmond Fitzgerald, of Boston, was duly elected an Associate Member of the Society. The following papers were read by title:

"Electrolytic Reduction of Nitrobenzene in Sulphuric Acid Solution," by Arthur A. Noyes and Arthur A. Clement.

"Influence of the Introduction of a Sulphonic Group upon the Power of a Developer," by A. A. Noyes and W. K. Gaylord.

"Additional Notes on the Prismatic Stadia Telescope," by Robert H. Richards.

An amendment to Paragraph 4 of Section VI of the By-Laws was presented and laid over to the next meeting.

The Chairman then introduced Mr. Walter B. Snow, of the B. F. Sturtevant Co., who read a paper on the "Blower System of Heating and Ventilation." The paper is published in the present number of the *Quarterly*. At its close the Chairman expressed the thanks of the Society to Mr. Snow, and after some discussion declared the meeting adjourned.

CLEMENT W. ANDREWS, *Secretary.*

# *THE FIRE HAZARDS OF ELECTRICITY.*

By WILLIAM BROPHY.

Read April 13, 1893.

In the following short paper on the "Fire Hazards of Electricity" I have attempted to present the insurance side of the question in as brief a manner as possible, as I understand the matter is to be fully discussed by gentlemen who, I have no doubt, will deal with this subject in a manner befitting its great importance.

On the introduction of the electric telegraph as a means of communication between distant points, the few wires stretched from pole to pole were not looked upon as a means of increasing the fire hazard, as their number was so few as not to be a serious hindrance to the fire department and the cases where atmospheric electricity followed the wires to the switchboard and instruments, causing small fires, were so rare as to hardly attract attention. By slow degrees, as the benefits of this great invention began to be appreciated, the wires began to increase; still, while they proved a hindrance, they were not looked on as a hazard to be seriously considered.

Later came the dial telegraph for communicating between local points and the stock ticker for sending out market quotations, but these increased the number of wires only slightly.

But after the invention of the speaking telephone and the perfection of the exchange system, then the increase of aërial wires was enormous; every available spot on roof or front of buildings was eagerly seized on by the busy linemen, often without due regard to the rights of owners or occupants. Lines of poles sprang up at all points, sometimes during the hours of night, and met the astonished gaze of the law-abiding citizens for the first time as they wended their way to their places of business. The location of these intruders was not always selected with a view to the comfort or convenience of these same good people, and often their protests were met by that trite saying, "Well, what are you going to do about it?"

With this enormous increase of electric wires the delays to the fire department became more frequent, and losses by fire were often greater than need be due to this cause; yet they did not endanger the lives of the firemen to any great extent, and were handled without fear.

Later came that new form of electric energy, the electric arc light. Gradually it worked its way into public favor, and gradually its power for mischief to the fire underwriters and owners of property became manifest by reaching the pockets of both. This was inevitable, owing to the first crude methods resorted to for the transmission of this new form of energy. The existing forms of insulation were not equal to the task of confining this greatly increased force within bounds, and, in fact, no other people in the world but our own would have permitted the introduction of an element fraught with such possibilities of danger to life and property with no real means for keeping it under control. But we are ever ready to take chances and assume risks in order to gain time or secure some improvement that will contribute to our comfort or add to our wealth.

With the introduction of this class of wires came another obstruction to the efforts of the firemen in extinguishing and preventing the spread of fires, and also a certain amount of demoralization in their ranks. Men who would face the flames, inhale poisonous gases, and stand beneath tottering walls without flinching, stood in wholesome dread of the arc-light wires. The former elements of danger they were familiar with, and could to some extent avoid, while the latter contained hidden, and to them mysterious, dangers that they knew very little of. To handle such wires or to come in contact with them meant injury or death. In addition to this they soon learned that the wires they had been accustomed to handle with impunity, and remove when an obstruction, were liable to become dangerous also; and, as a matter of fact, firemen are justified in refusing to handle electric wires in towns or cities where an arc-light plant is installed, unless during the hours when it is not in operation.

Next in order came the incandescent electric light, direct or low tension system. While the wires for this system proved another obstruction, they were not dangerous to life or limb; yet firemen, who are not expert electricians, looked upon them with mistrust. Later still came the electric power circuits. At first no greater than the usual 110-volt current was used, which is not dangerous to life or

limb. Later this was increased to 220 in order to reduce the cost of conducting wire.

Next came the transformer system of electric lighting, where a current of 1,000 to 2,000 volts is used in the primary conductors from dynamo to transformers. These were another obstruction and dangerous to person.

About the same time came the electric street railroads, with their trolley wires, feeders, span and guard wires. That these prove a serious obstruction at fires no sane man can deny. They also are a source of danger to the firemen, and contact with them is studiously avoided by those brave guardians of our lives and properties.

I have thus far dealt with but one feature of the fire hazards due to overhead electric wires. I now come to another — their liability to become the direct cause of fires.

First, is the liability to cause fires on the outside of buildings. Occurrences of this kind are rare, yet cases are not unknown. This is due in most instances to defective insulation at one or more points of the circuit permitting a derived circuit through or on the surface of inflammable material, and imperfect contact at binding posts and cut-out switches.

Next, we come to the greatest fire hazard from the overhead wires — the danger of electrical contact between the harmless low tension and the dangerous electric light and power wires. The arc, incandescent, power, railway, and alternating wires are capable of doing great damage in this way by sending currents greatly in excess of the safe carrying capacity of the smaller wires, and heating them sufficiently to cause the ignition of any inflammable substance in the immediate vicinity.

I will now consider the wires in the interior of buildings as a fire hazard, and will begin with those of the arc-lighting system. For the sake of securing sufficient mechanical strength, the size of wire used for this system has a much greater amount of conductivity than is necessary for safely conducting the current, so that no danger need be apprehended from overheating them. Where an abnormal amount of heat is produced in one of these circuits it is due to imperfect joints or connections, thus introducing an excessive amount of resistance at such points. There is also more or less danger from the arc lamp, due to broken globes permitting pieces of hot carbon to drop on inflammable goods, and also from improperly trimmed lamps, which

permit the burning out first of the carbons and then of the metal holders. This latter will surely cause trouble in many places.

Fortunately those engaged in the business of electric lighting recognize the wisdom of the practice of not concealing from view this class of wires, thus rendering the task of installing them with a reasonable amount of safety comparatively easy, and rendering their inspection less difficult.

Fire hazards from the incandescent system are confined wholly to the wires or conductors. The danger from the lamp need not be considered, though trouble can and does arise at times from the lamp socket. In a direct system, circuits, mains, and branches are supplied from a central station from one or more dynamos delivering current into one common conductor and thence through a system of feeders to the distributing mains. The electro-motive force necessary for the distribution of current in this system is not sufficient to cause serious injury by reason of shock to the nervous system, as it does not exceed 220 or 230 volts at the dynamo. But the quantity of current is sufficient to seriously burn a person under some circumstances, and would also under favorable circumstances cause serious loss by fire. The amount of current flowing from the generating station is limited only by the capacity of the dynamos and the number of lamps in use. The potential or pressure is as nearly constant as is possible to make it, but the amount of current is in proportion to the number of lamps. Whence, may be asked, comes the fire hazard from this system? A very natural question, and one that suggests itself to a great many people. But the fire hazard can be much greater from this than from the arc system. Hundreds of amperes of current are sent out over this system of feeders to supply lamps and motors, sufficient to melt down nearly if not all the interior wires in many buildings if, by reason of one of the many causes that suggest themselves to those familiar with the subject, an abnormal flow of current takes place over them.

You may ask, how can this occur? Current flow is regulated by the electro-motive force or pressure and resistance, or, if you please, friction. To supply a given number of lamps, or given size of motor, a given size of wire is necessary. The filament in the lamp affords a path of very high resistance for the current. As they are connected up in multiple the greater the number of these paths and the less the total amount of resistance. If through ignorance or motives of econ-

omy the supply wire is too small, heat is generated in the wire; and if the number of lights is sufficiently in excess of the safe carrying capacity of the wire, it can be brought to a white heat or even melted — a dangerous process near inflammable material.

If the wires are properly proportioned, and through any means those of opposite polarity (positive and negative) are brought into metallic contact, a path of low resistance is then established and an excessive flow of current results with the same consequences as before. Derived circuits established to and through the earth, caused by defective insulation, even though the points of contact be widely separated, will bring about this same result.

It is true that safety fuses are brought into play to prevent occurrences of this kind; but it is not an unusual thing to find fuse wires at the junction of circuits and branches far in excess in carrying capacity of the wires they are designed to protect, and it is not unusual after the fuse wire has performed its functions by melting to find it replaced by one whose fusing point is many times in excess of the original; and I have known cases where, after the failure of the largest fuse wire to maintain the continuity of the circuit, copper wire was substituted therefor.

The next hazard is from the fuse blocks or bases. The earlier types of these were of wood. Contact between wires and fuse being secured under screw heads, the inevitable shrinkage of the wood destroyed the contact, and heat or a series arc was the first result, and later a fire, insignificant or of considerable magnitude according to circumstances. Too often these devices were concealed from view, thus increasing the hazard.

Next come the switches for turning on and cutting off this supply of current. When mounted on wooden bases they were capable of doing all the mischief ascribed to the wooden base cut-outs. In addition to this may be cited imperfect contacts, introducing an excessive amount of resistance and increasing the temperature to an unsafe point. The inexcusable practice of placing switches of insufficient capacity is sure to bring about the same results.

That undesirable trio, the combination fixtures for gas and electric lights, the cheap insulating joint, and wood or fiber base cut-out concealed under the metal canopy of the fixture, has been and is now another fruitful source of trouble and added fire hazard. The heat from the gas burners on a large fixture causes the fiber insulation to

shrink, permitting the gas to escape in small quantities at first, but steadily increasing in volume. The contact between screw head and fuse is destroyed from the same cause, a slight arc established, the escaping gas ignited, the fiber in the joint burned, and a burning gas flame limited only by the size of the pipe is the result.

Next in order comes that twin brother in iniquity of the swinging gas jet, the so-called flexible cord, to the ends of which are suspended so many incandescent lamps. The best of this is not safe in some locations, such as show windows or any other place where it is in close proximity to inflammable goods, while the cheaper grades are positively dangerous in nearly all places. While the use of this may be admissible for suspending lamps in the usual way in buildings which in themselves are of slow burning construction and contain little that is inflammable, the practice of fastening it to the walls or ceilings, either by means of cleats or staples, or concealing it between floors and partitions cannot be too severely condemned. Such a practice adds another to the fire hazards of electricity.

Next come the wires for incandescent electric lighting, their character, and the methods of installing them. It goes without saying that the very best of insulating covering is none too good for electric light wires. In many positions it should be water-proof, though there are cases where this is not necessary. Another desirable quality it should possess is non-inflammability, but very little of the best grades of insulation for wires possesses this desirable feature. Wires covered with any known grade of insulation, held in place by wooden cleats, add to the fire hazard to a greater or less degree, depending on their location, the distance between opposite poles, and the care with which they are placed in position. Wires that are concealed between floors, ceilings, and partitions, where not supported on non-inflammable insulators, and that are permitted to rest on gas, steam, water, or hot-air pipes, or other conductors, dependence being placed on the covering of the wire to prevent electrical contact, add to the fire hazard. Wires of opposite polarity run through a single hole in wooden joist, beam, stud, or partition, and laid side by side without a proper amount of separation, add to the fire hazard, due to the fact that the best form of insulation has a limited life, and to the other fact that the ever-present rodent finds some forms a dainty morsel. As a result of his feast an arc may be established, and if the insulation is highly inflammable a fire between the ceilings and partitions is rather apt

to follow. Loose connections and poorly made joints are another addition to the fire hazard. Joints when improperly made and not soldered soon become a source of danger. Solder alone will not insure a perfect joint and immunity from excessive heat at this point.

The practice of inclosing two wires of a circuit covered with a high grade of insulation in an insulating tube that is itself highly inflammable is another addition to the fire hazard.

All the causes assigned for increased fire hazard to this system of electric lighting apply to the system known as the alternating or transformer system, with the exception of the fact that the amount of current it is possible to convey into a building is limited to the capacity of the transformer. The lamps used on this system are usually what are known as fifty volts, and the current necessary to bring them to a state of incandescence is about one ampere. A 75 light transformer then could deliver only about 75 amperes.

I have endeavored as far as possible within the limits of this paper to give most of the causes for increased fire hazards due to electricity. It is due, however, to those engaged in the various branches of electric industries and those who use electrical energy for light, power, or the transmission of intelligence to state that many of the devices I have condemned are not now manufactured, although many are still in use, and that many of the bad practices that I have condemned are not indulged in by reputable men and firms.

I firmly believe that electricity in the service of man can be rendered docile and harmless, but to point out the manner in which this desirable end can be attained is beyond the scope of this paper and the limit of the time allotted to me at this meeting. This, however, might be made the subject of another paper.

I will now close by saying that the man or firm who will take advantage of the limited knowledge of electricity possessed by the average citizen and install electric wires in such a way as to increase the fire hazard should be deemed guilty of a misdemeanor, and, if fire results, should be deemed guilty of arson. The electric lighting company who would connect its service wires and furnish current to a building unsafely wired should be deemed an accessory before the fact, and punished accordingly.

It is within the power of those engaged in installing electric lights and wires and furnishing electricity for light and power to greatly reduce the fire hazard and stop the complaints of underwriters of the increased number of fires due to electricity.

## *FIRE RISKS AND ELECTRIC WIRES.*

By H. F. PARSHALL.

Read April 13, 1893.

On the part of the General Electric Company I wish to state that its interests are not confined to any one system of transmission. It has extensive plants for the manufacture of cables of every description, *i.e.*, lead-covered cables, steel-armored cables, specially fitted for underground and submarine work; water-proof and rubber-covered cables, specially fitted for overhead work. It also has an extensive plant for the manufacture of underground tubes (as they are called), which have been extensively used by the Edison Company for a number of years, and have been found, without exception, satisfactory.

In order that it might most intelligently advise the public as to what system could be used with greater safety, the statistical department addressed a circular letter to the chief engineer of the fire departments of the principal cities in the United States of 20,000 inhabitants and upwards for information covering the following points for the municipal fiscal year most nearly conforming to the calendar year 1891:

Total number of fires from all causes.

Total damage caused by same.

Total number of these fires which may be attributed to electric lighting circuits.

Total damage caused by same.

Total number of fires attributed to electric circuits of every nature.

Total damage caused by same.

Out of 165 cities coming within the scope of this inquiry replies were received from 82. These replies were tabulated, and show that about 1.23 per cent. of all fires are caused by electric circuits, or about one fire in 75. Of these .13 of 1 per cent. were attributed to power circuits. The damage done by these fires was about 1.02 per cent. of

the total loss from fires — .78 per cent. from lighting circuits, .23 per cent. from power circuits. In other words, the loss due to electric circuits is about $1.02 out of each $100 due to all causes.

It appeared from the figures that Boston had been particularly unfortunate from fires caused by electric wires, some 2 per cent. of the alarms being caused thereby. It is to be noted, however, that one half of these alarms were caused by overheated thermostats and fires on street cars. The amount of damage done was uncertain, since it has been proved by some of the highest authorities that some of the large fires that were attributed to electricity were due to other causes. The loss in other large cities, however, was much smaller. In Philadelphia the number of alarms from electric circuits was only 0.7 per cent., and the loss therefrom was only 0.1 per cent. In St. Louis the number of alarms from electric wires was only 0.5 per cent., the loss therefrom only 0.04 per cent. It seems reasonable to suppose that a greater loss per fire in Boston might be due in a considerable measure to the narrowness of the streets and the greater difficulties in fighting conflagrations when under way.

Taking into consideration that most of the fires attributed to electric currents were on circuits that had been installed a number of years ago when the art of wiring had not attained its present perfection, it was not apparent that any decided recommendation could be made by the General Electric Company from the standpoint of fire risks. As, however, underground systems are not exposed to storms, and therefore offer a more reliable service, the underground system of tubing has been recommended for general use in low tension lighting systems.

From December 31, 1890, to January 31, 1892, there were 260 fire alarms here in Boston sent out, from careless use of lamps, candles, kerosene oil, and matches, as against twenty-six due to electric wires, most of those due to electric wires causing no loss.

With respect to internal wiring in general the following points are worth considering:

1. That a sufficient price shall be paid for all work done to insure reliable work and competent inspection.

2. That only those contractors shall be considered whose reputation is worth more than the profits on any particular installation.

3. That a liberal allowance of copper shall be made in all the mains, so that when an increased number of lamps shall be required

(as almost invariably happens) the mains first installed shall not be dangerously overloaded. As a practical example of this I have in mind a building the drop of which is now 20 per cent., which was originally thought to be amply wired. Such a state of affairs, I am led to believe, is not uncommon, and is neither economical from the standpoint of the investor nor safe from the standpoint of fire.

4. No electric wire should be run into any building without providing automatic cut-outs, so that if the current in that circuit exceeds its safe carrying capacity the circuit in the building will be automatically cut out. Telephone and telegraph wires have been strung indiscriminately, and many of them have afterwards been abandoned but not removed. These wires are small and easily deranged, and as no one has kept them repaired they are a considerable source of menace. Practically all of these abandoned wires are without safety devices for cutting them out of circuit, so that when one of these wires drops across a trolley line there is the greatest danger. Many of these wires were strung before high tension wires had to be considered, and are in places where there is the most imminent danger therefrom. No excuse exists for not putting safety devices on the circuits of all such wires since the currents normally carried thereby are exceedingly small and the increase of resistance by such devices is infinitesimal compared with the total resistance of the circuits. Further, if the safety devices are intelligently designed no interruption of service can be caused therefrom.

5. All low tension wires (*i. e.*, wires adapted to carry only small currents at low voltages, such as telephone, telegraph, messenger, and signal wires) should be placed underground. We have had sufficient experience with such to enable us to state that this can be safely and economically done. Aside from the increased fire risks caused by such wires being overhead, the numerous severe storms here in New England make the service of such an overhead system unreliable.

Having now safely disposed of all low tension wires the question arises what is to be done with the high tension wires? This problem does not admit of easy solution. It is obvious that with all low tension wires (which are generally uninsulated) underground, far less trouble is to be expected from high tension wires, since with the exception of the trolley wire these high tension wires are

generally thoroughly insulated and of such size that they are not easily deranged.

With respect to the feeders and mains of street railway systems it is to be borne in mind that these feeders and mains carry considerably more power and at higher tension than those of any other class of circuits. Hundreds of horse-power are, in fact, sometimes carried on a single large cable, so that in case of the short circuiting of one of these cables, even if under ground, considerable trouble might occur to any telephone or telegraph wires, water or gas pipes in the vicinity. Further, these mains are subject to greater fluctuation of service than any other class of mains, so that to have the same safe margin for the maximum current carried the cost of these mains would in many cases be prohibitive.

It may eventually be found practicable to put this class of wires under ground, but it should be understood that there are difficulties to be surmounted that do not exist with other classes of electric wires.

It is frequently stated as a possibility that the trolley wire can be safely put under ground. Experiments have been made costing hundreds of thousands of dollars, and none of them have indicated the practicability of doing this. The conditions in this country are not favorable for the construction of satisfactory conduits. This climate is so severe that the effective insulating of the contact wires from the earth is exceedingly difficult. The problem of making contact from the car with the underground wires is the one above all others in conduit work that is most difficult. The width of the wagon tires and sleigh runners in this country is such that only a very narrow slot is permissible, and to make a durable contact plow to run in the width of slot to-day permissible is out of the question. Contact plows of nearly every description have been devised, but not one of them has proved sufficiently successful to warrant recommendation for general use. Considering, however, that there are some 240 miles of exposed trolley wire in Boston, and that the loss by fire from power circuits in the period named above was only 0.01 per cent., also the statements made with respect to abandoned telephone and telegraph wires, it is evident the *trolley* wire does not perceptibly increase the number of fires.

With respect to guard wires that have been used over trolley wires: it is apparent that with other wires placed under ground

any theory regarding the usefulness of these guard wires would have to be abandoned. Even with the present state of affairs I believe these guard wires are of most doubtful advantage. They certainly contribute to make the present trolley system more unsightly than it would otherwise be.

It appears to the writer that the principal difficulties to be anticipated in power circuits are in connection with battling with fires. In general; while the voltage employed for railway circuits is such that there is no danger to life directly therefrom, the favorable opportunities for getting a shock in the vicinity of a fire to some extent embarrass and impede the action of the firemen, since when a fireman has received a shock he immediately lets go and is best satisfied not to repeat the experiment, as he is not convinced that he has received the full effect of the electro-motive force acting. To guard against occurrences of this sort, and at the same time avoid troublesome delays to passengers, emergency corps might be organized by the street railways with alarms operated by the city fire department, since by adopting this means there would be the least delay in getting these emergency corps in action; they should, in fact, if possible, be on the ground before the firemen. With emergency corps working with the same efficiency as the fire companies, and with a proper system of alarms, there should be no trouble to the firemen from electric wires, and the interruption of the traffic of the street railway companies would be minimized.

In conclusion, with respect to electric circuits, it should be said that the use of the electric light tends to greatly diminish the number of fires; that there is no other system for the transmission of great amounts of energy that is attended with so little danger; that the conveyance of energy by means of electricity has in general been found so simple that in many cases (in times past) the most ordinary precautions have been neglected; that the danger therefrom is small compared with any other means for conveying the same amount of energy; that even with the tremendous amount of energy so conveyed the danger has been rendered infinitesimal by competent supervision and improved apparatus; that low tension wires are to-day to be considered most dangerous from a standpoint of fire risks, and that the danger therefrom can be eliminated by reasonable means.

# *THE BLOWER SYSTEM OF HEATING AND VENTILATION.*

By WALTER B. SNOW, S.B.

Read May 11, 1893.

From the open fire of the savage to the fireplace, the stove, the furnace, and the present perfected systems of steam, hot water and hot air heating, the art of heating has kept pace with increased human sensibilities and the desire for more refined methods.

In matters of ventilation, increased knowledge and personal demand have crystallized public opinion into statute laws looking to adequate methods for school, theater, hospital, church, and factory.

The earlier authorities based their calculations of necessary air-supply upon, and made it practically equal to, the actual volume expired from the lungs; just as though a person could inspire from one reservoir and expire into another. We now know that under ordinary conditions the vitiated air expired immediately and intimately mixes with the surrounding atmosphere, so that the question of ventilation becomes merely one of diluting a polluted atmosphere to such an extent as to confine its vitiation below some predetermined maximum.

Carbonic acid gas, of which we hear so much in its relation to ventilation, is not in itself a dangerous impurity when present in such proportion as we find it even in the worst ventilated rooms; but, fortunately, it is a direct measure of the character of the atmosphere with which it is associated, so that its presence as determined by simple methods is relatively indicative of the existing proportion of positively injurious vapors, gases, and suspended particles.

In the atmosphere of the open country there is present from 3 to 4 parts of carbonic acid gas in 10,000 parts of air, while in that of an inclosed apartment in which a musty odor is barely perceptible to one entering from out-of-doors there will be found not less than 6 or 7 parts in the above-named volume. Good ventilation is measured by the presence of not more than 6 parts, and

fair ventilation by not more than 8 parts of carbonic acid gas in 10,000. It is readily deducible that, to maintain a proportion of 6 or 8 parts in an apartment continuously occupied by a given number of persons, 3,000 or 1,500 cubic feet of air will be required per hour per individual according to the proportion of carbonic acid.

An ordinary schoolroom, containing 56 pupils and teacher, would thus hourly require from 171,000 to 85,500 cubic feet — equivalent to passing through the room once in every 5 to 10 minutes a volume of air equal to its entire cubic contents.

The State Inspectors of Massachusetts require 30 cubic feet of air per pupil per minute for schoolhouse ventilation — not from hygienic deductions, but because it appears upon investigation to be the practical limit attained by existing methods in this Commonwealth.

Their original attempt to secure 50 cubic feet of air per head per minute would have resulted in remodeling, with scarcely an exception, every school building in the State. *Financial* outweighed hygienic influences, and the limit was dropped to 30 cubic feet.

Almost all existing systems, particularly those installed prior to the last decade, depend for the necessary air movement either upon the natural action of vent flues and foul air shafts or upon their increased efficiency due to heated stacks or steam coils. All such methods are, however, largely at the mercy of climatic conditions. As the external temperature rises they must of necessity become less effective; heavy winds will ofttimes reverse their action, and damp and muggy days are noticeable in their effects. They are unstable, untrustworthy.

Some means, always positive, always reliable, must be adopted. Nothing short of a positive acting mechanical device is capable of accomplishing the desired results. The fan-blower stands preëminent as most economical of power for air volume moved, as most easily applied, and most readily operated.

The past ten years have witnessed the rapid introduction of the fan, not only as an adjunct to old systems of ventilation and heating, but more prominently as the primary feature of a newly developed method of hot air heating. The blower system of heating and ventilation as herein described comprehends only that method by which ventilation is secured under plenum conditions, that is,

when the air is forced into rather than exhausted from the building, and comprises in its completeness a steam-heater or heaters, a fan, driven by some type of motor, and a system of ducts and flues through which the air is forced to the various apartments of the building.

Although the State law now requires adequate ventilation in factory buildings, yet it must be admitted that in the introduction of the blower system the owner's first motive is usually mercenary rather than humanitarian. But the blower system fortunately possesses this particular feature, considered solely as a heating system, namely, that in order to heat successfully it is necessary to supply a volume of air sufficient at the same time to thoroughly ventilate any ordinary factory structure where the processes are no more than ordinarily objectionable.

The introduction of the blower system is, therefore, divided between two great classes of buildings.

First, where heating is preëminent and ventilation is merely incidental, and —

Second, where the system of ventilation is of primary importance, and heating is necessarily combined with it for successful operation rather than introduced as an independent system.

To the first class belong almost exclusively all manufacturing buildings, storehouses, drying-rooms, exposition buildings, and some offices and stores.

In the second class are those buildings in which specially objectionable processes are carried on — hospitals and asylums, all halls of audience (including theaters, churches, and schools) — and stores and offices not included in the first class.

The enterprising manufacturer is quick to appreciate his financial interest in the provision and maintenance of an atmosphere in his factory that exhilarates rather than wearies his employees; for a direct monetary return can be shown in the improvement in quantity and quality of work resulting from the introduction of the blower system with pure air and a comfortable temperature.

The blower system has met with special approval at the hands of the manufacturer on account of the utilization of his exhaust steam without imposing unnecessary back pressure on his engine. Doubtless one great element in its success in the mill and factory has been the usually excellent attention which it receives. Every manufactory

of reasonable proportions has its own power plant and its own engineer, to whom is usually assigned the control of the heating system.

Considerations of economy and the before-mentioned idea of the owner, that *heating* is the preëminent feature desired in the application of the system in a factory, have much to do with the location of the apparatus. To secure economy in heating where improved ventilation does not enter into the question, the apparatus is frequently arranged so as to take its air-supply entirely from within doors, thereby simply turning the air over and over within the building. As the cost of ventilation is necessarily measured by the volume of air, at the temperature of the room, which is removed or caused to escape in a given time, it is obvious that this expense may be practically avoided by the above-mentioned plan of turning the air over and over. There is even then an incidental leakage resulting in a degree of ventilation considerably in excess of that occurring with any system of direct steam heating. To this end, in a one-story structure the apparatus should be placed as near the center as possible, so that the air may be drawn back to it from all sides.

Dependent upon the character and construction of the building, one of two general methods of distribution may be adopted. The first and most common is by a more or less extended system of metal ducts or pipes, almost universally constructed of galvanized iron on account of its durability. Such a system is the only one practicable in wooden structures. In brick buildings, particularly those of two or more stories, brick ducts and brick vertical flues are the most convenient, and, as usually applied, do not encroach upon valuable interior floor space.

The one-story structure with brick, wood, or metal sides, with sloping roof surmounted by skylight or monitor, forms to-day the model for the foundry and the machine, boiler, or blacksmith shop, while its use is rapidly extending to other trades. In such a building some arrangement of galvanized iron distributing-pipes is compulsory, for the brick duct and flue become too expensive proportionally to the cubic contents to be heated.

In comparatively narrow wooden structures, where it is a question of galvanized iron pipe or nothing, the main distributing pipe extends lengthwise of the basement and there connects with risers carried up alongside of the supporting columns of the building, from which the air is discharged towards the walls through properly located outlets about 8 or 9 feet above each floor.

The ideal installation of the blower system is in the three or four story brick factory of the type of the ordinary cotton mill, where the heated air is conducted from the apparatus through the basement to the bases of special pilaster flues located at regular intervals along one side of the building.

Figure 1 (p. 108) will serve to show the general construction of the duct and detail of a flue. The duct itself is constructed of brick, extending along the interior of the basement wall, and is provided with either a flat or arched top of approved and air-tight material, or is made quadrant in form, thereby securing for a given expenditure of material the maximum area for passage of air.

At distances varying from 40 to 75 feet, the piers between the windows are carried out and form the pilaster flues. Upon each floor, at least one foot below the main floor timbers which are supported by the piers, there is placed in each flue a special damper, as represented in Figure 2, which, as it is opened, extends into the flue and acts as a deflector to throw a portion of the air into the room, this proportion being controlled by the operating mechanism.

Most prominent among the buildings in which the ventilation may be considered of primary importance are those in which persons remain for several hours closely seated and practically inactive, as is the case with an audience in a church or theater and with the pupils in a schoolroom. Here, the *per capita* air space in the room is at its minimum. In the best modern schoolroom there is usually an allowance of 250 cubic feet of space per occupant; but in many theaters and halls this figure is reduced as low as 75 to 100 cubic feet to each person.

In the ordinary schoolroom a supply of 30 cubic feet per head per minute would necessitate changing the entire volume of the room once in about eight minutes, while in a hall with only 75 cubic feet of space for each member of the audience such a supply of air would require a complete change once in every two and one half minutes.

It is extremely difficult, in fact practically impossible, to so introduce such an excessively large volume of air under these latter conditions without creating objectionable draughts about the occupants.

In this climate a perfect system of heating and ventilation applied to a building of the aforementioned class, should,

First, maintain within each room a mean temperature of 70° F., irrespective of changes in external temperature, with a total variation

DETAILS OF INSTALLATION IN A BRICK FACTORY.

FIG. 1.

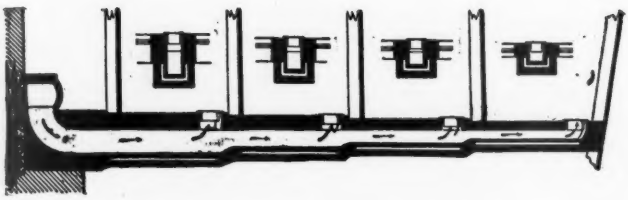
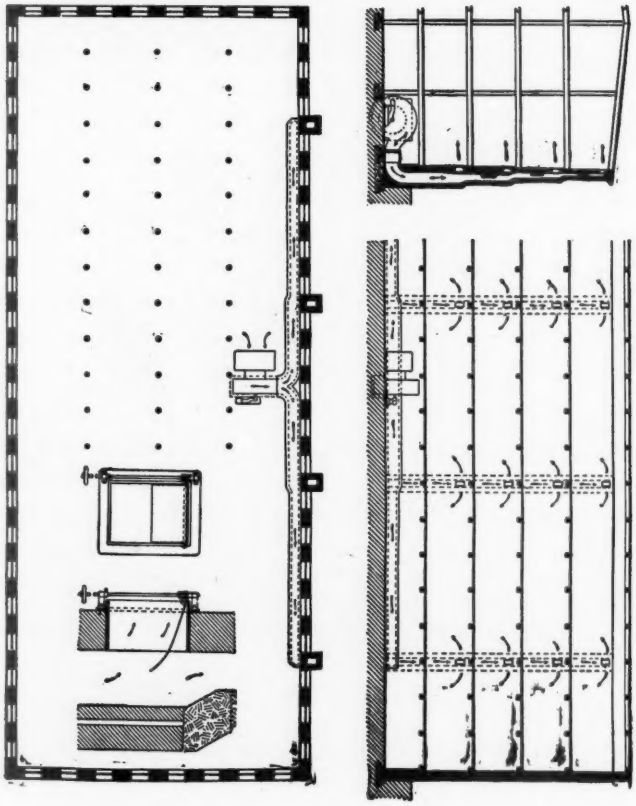


FIG. 2.



of not over 2° above or below this mean in any occupied portion of the room.

Second, supply to the room, under all conditions of indoor and outdoor atmosphere, a constant predetermined volume of air, and deliver it without creating objectionable draughts and in such a manner as to be thoroughly and efficiently distributed throughout the apartment.

This second requirement may be even so exacting as to demand a constant indoor temperature, with variable supply of air proportioned to the number of persons occupying the room at any given time. Assuredly, with no arrangement or device can the air-supply be more readily proportioned to the requirements than with the blower system. Doubtless at the present time more attention is being given to improvement in schoolhouse ventilation than to that of any other class of structures; therefore a discussion of the application of the blower system to buildings of this type must throw a strong side light upon the methods to be adopted in all so-called halls of audience.

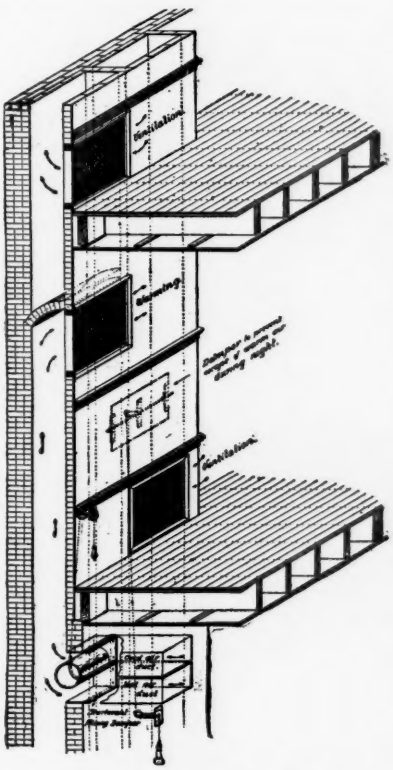



FIG. 3. ARRANGEMENT OF HEAT AND VENT FLUES FOR SCHOOLHOUSE.

The ordinary schoolhouse, with its brick partition walls, presents a most excellent opportunity for the economical placing of the necessary flues, for they may be grouped along the interior walls and provided with inlet openings about 8 feet above the floor and vent openings at floor level. A flue serving to supply hot air to the first floor may, by the insertion of a header above the heat opening, serve also as a vent flue for the room above. This arrangement is indicated in Figure 3.

By making the area of the vent register and flue the same, respectively, as that of the supply register and flue, the discharge of air — at a lower velocity than it enters — is sufficiently restricted to produce a plenum condition within the room, not only preventing inward draughts, but compelling the surplus of air to escape through cracks, crevices, and even through the porous walls.

The varying exposures of the rooms of a school building require that more heat shall be supplied to some than to others. The sunlit, southerly room, perhaps still more favored by being over the boiler, may be kept perfectly comfortable with a supply of heat that perchance will barely maintain a temperature of 50° to 60° F. in a room on the opposite side of the building, exposed to high winds and shut off from the warmth of the sunshine. With a constant and equal volume of air supply to each room, it is evident that its temperature must be directly proportional to the cooling influences within and around the room, and that no building is properly heated and ventilated where the temperature cannot be varied without affecting the air-supply.

To this end, air of a given temperature may be conducted to the base of each flue and there tempered to a degree suitable to the requirements of the room supplied. Two methods appear:

The older arrangement consists in heating the air by means of a primary coil to about 60° F., or to the minimum temperature required within the building. From the coil it passes to the bases of the various flues, and is there still further heated by secondary or supplementary heaters.

Such an arrangement is operated in the Walker Building of the Institute, where distribution ducts are omitted, and the entire sub-basement serves as a large plenum chamber containing air under slight pressure heated to about 60° F. by the main coil.

Under the second and more recent method a single heater is employed, the supplementaries are discarded, and all the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while variety in temperature of air supplied to the other rooms is secured by mixing with the hot air a sufficient volume of cold air at the bases of the respective flues.

This result may be best accomplished by designing a hot blast apparatus so that the air shall be forced rather than drawn through the heater, and by providing a by-pass through which it may be discharged without being heated. An example of this type of apparatus

is shown in Figure 4, provision for the discharge of the unheated air being made above and separate from the heater pipes. Extending from the apparatus is a double system of ducts. At the base of each flue is placed a mixing damper, as shown in Figure 3, usually controlled by chain from the room above, and so designed as to admit either a full volume of hot air, a full volume of cold air, or to mix them in any desired proportion without affecting the resulting total volume delivered to the room.

Where perfect regulation, independent of the teacher, is desired, the damper may be operated by a thermostat in the room with which the flue connects.

The *hot and cold system*, as this is familiarly known, accomplishes at less expense, with greater rapidity and equal certainty, the results

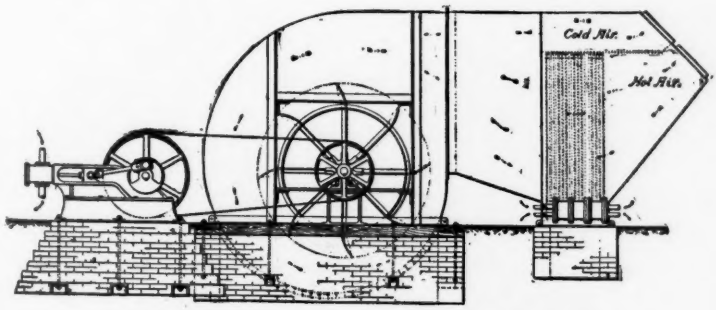



FIG. 4. HOT BLAST APPARATUS WITH COLD AIR BY-PASS.

obtained by the more complicated method previously described, and is being extensively introduced in the modern schoolhouse wherever the blower system is applied.

The hall and the church are in reality but enlarged schoolrooms as regards their treatment by the blower system. The same vital requirement holds; that the temperature must be maintained independent of volume of air admitted, while the difficulty of satisfactorily admitting the required air supply is increased by the closer seating of the audience.

The theater presents far more complication than the hall; its three parts — stage, auditorium, and lobbies — may at one moment be essentially one and the next be rendered practically independent. The auditorium is usually thoroughly protected by the lobbies or the walls of

adjacent buildings, so that the heat loss is reduced to a minimum and during a performance it becomes a question of cooling rather than warming the occupants.

A novel arrangement of the blower system is in operation in the New York Music Hall. The main concert hall, seating 3,000, and the recital hall, with a capacity of 1,200, are supplied entirely through perforated ceilings, whence the air passes down over the persons of the audience and escapes through a multitude of openings in floor and risers. This unnatural movement of the air against its own impulse must be facilitated by exhaust fans connected to the area beneath the floor in addition to the plenum fans for forcing in the fresh air.

The rapid improvement in theater ventilation certainly indicates that the enterprising manager sees therein another inducement to the theater-going public to patronize his individual house in preference to one where the air is foul and oppressive, although the dramatic attraction may be equally good.

The requirement of large air volume *per capita* in hospitals and asylums, particularly in contagious wards, necessitates positive and ample means which can only be met satisfactorily by the fan, standing as it does, capable, according to its size, of supplying any amount of air required.

The store with its extended floor areas, and the office building with its multiplicity of small rooms, call for arrangements peculiarly their own.

The ready adaptability of the blower system to diverse conditions forms one of its salient features. Not only is it a success as a heating and ventilating system, but as a means of drying materials of all kinds it has long been in use in many industries of this country. Lumber, wool, cotton, leather, fabrics, paper, and the like, are most expeditiously dried by this system, with its ample supply of warm air to furnish heat for vaporization of the water and the necessary absorptive power for taking it up and carrying it away.

The hot and oppressive summer day may be made more endurable in shop, office, or place of amusement by the mere operation of the fan and its resulting change of air within the room, while positive comfort may be secured by passing cold water through the pipes of the heater across which the air is drawn, or by exposing ice to the air currents prior to their entrance to the fan.

In place of the complicated and expensive appliances frequently

introduced in the textile mill for sufficiently humidifying the atmosphere to prevent the troublesome effects of frictional electricity, there is required with the blower system only a water spray in the main air duct.

The public at large has been slow to appreciate the necessity of ample and thorough ventilation, but in this State at least the building and State inspection laws keep the subject ever before the eyes of the proprietor, the architect, and his client.

As the mission of ventilation is to remove foul and supply fresh air, it is at once evident that in this process of removal there must be continuously carried from the room a large amount of heat, for all the air escaping must be of the same temperature as that of the room itself. This loss is incidental to any system or arrangement by which ventilation is secured, and it must be made good by imparting the necessary surplus of heat to the air admitted.

It is not strange, then, that the cost is greater for heating a well-ventilated room than one which is tightly closed.

The advantages of the blower system may be summarized under two main heads:

First, adaptability and convenience.

Second, efficiency and economy.

The early consideration of the system before the plans of the building are completed has, of course, much to do with its adaptability and the convenience with which it may be introduced.

The centralizing of the entire heating surface in a single room and within a single sheet-iron jacket avoids all danger by fire, prevents the possibility of damage by leakage, and removes all anxiety regarding the freezing incident to isolated coils. A single valve serves to control the temperature of all air admitted to the building, so that the thoroughly installed system, with its governed engine, automatic return water apparatus, damper regulator, and its thermostatic control, is rendered so completely self-controlling that the attendant's care is usually reduced to supplying sufficient coal to the boiler.

The system is positive in its action at all times, the air is put where it is wanted, not merely allowed to go. The pressure created within the building is sufficient to cause all leakage to be outward, preventing cold inward draughts and avoiding the possibility of drawing air from any polluting source within the building itself.

Absolute control may be had over the quality and quantity of air

supplied. It may be filtered and cleansed, heated or cooled, dried or moistened at will.

By means of the hot and cold mixing damper, the temperature of air admitted to any given apartment may be instantly and radically changed.

The *efficiency* and *economy* of the system must of necessity be considered under *first cost* and *running expense.*

Circumstances so decidedly alter cases that an arrangement economical and easy of introduction in one building may prove very expensive in another. In the majority of cases, however, the blower system, regarded simply as a method of heating, may be installed for less money than any other system of equal efficiency.

Wherever the flues can be formed in the walls and the distributing ducts are of moderate extent the system will figure less in first cost than any other capable of attaining the same results and of supplying the same amount of air. The primary cost of a fan is less than that of any other device for moving the same amount of air.

The large volume of air passing through the heater causes a condensation of steam so great that one foot of heating surface is rendered the equivalent in efficiency of three to five feet in the form of the ordinary direct radiator exposed in the room. This saving in heating surface offsets the additional cost of fan and motor.

As directly bearing upon this point, Professor Woodbridge has stated with regard to the installation in the Walker Building that the saving in piping due to rapid condensation in the coils, as there arranged, was sufficient to pay for the fan, together with an attached engine, had that arrangement been adopted.

In all fairness, the operating expenses of any system must be compared upon a basis of similar conditions. The blower system when taking its air from out-of-doors cannot be properly compared with any system of direct radiation, for in the latter is lacking the advantage of the ventilation incidental to the operation of the former. But when the blower system rehandles and reheats the air within the building without outside supply, the comparison becomes more reasonable, although there will still continue to be a considerable change of air due to leakage.

A six months' continuous test at the Globe Yarn Mills, Fall River, has presented data exceptionably valuable for comparison. Of two mills, nearly equal in size and equally exposed, one was fitted with an

overhead direct heating system, the other with the blower system. In mill No. 1 the average temperature was 70°, in No. 2, 78°.

The cost of fuel per unit of space warmed was, however, in the proportion of 100 in the direct heated mill to only 64 in the mill heated by the blower system.

The cost of janitorial service enters as an important factor in any building other than a manufactory. The blower system has been adversely criticised because of the experience required in its operation. In point of fact it has been attempted by committees and school boards to place the control of the system in the hands of men who could sweep floors and shovel coal but didn't know the difference between a boiler and an engine. It is not greater intelligence, but a different order of intelligence, that is required.

When exhaust steam that would otherwise be thrown away is utilized in the heater, its cost must be considered as practically nothing. The condensation in the heater of all the exhaust steam from the special fan engine reduces the cost for motive power to a minimum.

As to comparisons regarding cost of repairs much may be said pro and con; but the character of the machinery, its few parts, slow speed of engine and fan, the sectional construction of the heater, the lack of complication of valves, the concentration of the plant at one point, and the fact that it is under the care of one man, are greatly in its favor.

## *COLLEGE ATHLETICS.*[1]

By FRANCIS A. WALKER, LL.D., President of the Institute.

I TRUST it will not be deemed beneath the dignity of this occasion that I should ask your attention to a few thoughts regarding college athletics. No theme is to-day of greater consequence to the colleges and universities of our land, whether as influencing school discipline or as affecting the standard of scholarship. Alike those who applaud and those who deprecate the growth of athletics must admit the importance of the subject.

The past ten years have witnessed a remarkable development in the direction indicated, which we may well pause to consider. The rising passion for athletics has carried all before it. Thus far, at least, there is no sign of reaction, or even of the exhaustion of the forward impulse. Honors in football, in baseball, and in rowing have come to be esteemed of equal value with honors in the classics, in philosophy, or in mathematics; and if the movement shall continue at the same rate it will soon be fairly a question whether the letters A.B. in the college degree stand more for bachelor of arts or for bachelor of athletics.

Among instructors and the governing bodies of our colleges there is a wide difference of sentiment on the subject. Some applaud, some doubt, some disapprove; others are simply dazed and know not what to think, or suspend all judgment waiting to see how much farther the rising tide will encroach upon the shore. In the larger community there is, perhaps, an even more pronounced divergence of opinion. Few college presidents or professors but see some good in the new movement and sympathize largely with the enthusiasm of their pupils. But there is a host of editors, preachers, and men of affairs in the outside world, and a host of parents and guardians more directly concerned, who are sure that it is all of evil; that the colleges are simply going wild over athletic sports, preparing the way for the downfall of the traditional system of education. To many of these it is a monstrous thing that large bodies of young men should give themselves up to contests of skill and strength, and that larger bodies still should find in these contests the chief interest of their college life.

[1] An address before the Phi Beta Kappa Society, Alpha of Massachusetts, at Cambridge, June 29, 1893.

Fairly to approach the subject, we need to consider the state of things which existed prior to the war of secession; in other words, to go back just one human generation, as a human generation is usually computed. In those days gymnastics held but a small, a very small, place in American colleges; while throughout the wider community there was almost no athleticism. The two most important exceptions to the latter statement were found in the occasional outlawed and always disreputable prize fight, generally with some international complication, genuine or manufactured, for the sake of stimulating public interest, and in a small amount of rather poor, unscientific boat-racing. Almost no honor was then given to a young man because he was strong, swift, courageous, or enduring. The college hero of those days was apt to be a young man of towering forehead, from which the hair was carefully brushed backwards and upwards to give the full effect to his remarkable phrenological developments. His cheeks were pale, his digestion pretty certain to be bad. He was self-conscious, introspective, and indulged in moods as became a child of genius. He had yearnings and aspirations, and not infrequently mistook physical lassitude for intellectuality, and the gnawings of dyspepsia for spiritual cravings. He would have gravely distrusted his mission and his calling had he found himself at any time playing ball. He went through moral crises and mental fermentations which seemed to him tremendous. From the gloomy recesses of his ill-kept and unventilated room he periodically came forth to astound his fellow students with poor imitations of Coleridge, De Quincey and Carlyle or of Goethe in translation.

Not all college heroes of those days were of this familiar type. Sometimes they were thunderous orators, more Websterian than Webster, who could by a single effort lift themselves to the full height of perorations which in the senate or the forum are the culmination of great arguments and of many a passionate appeal. Sometimes, though more rarely, the college hero was a delightfully wicked fellow, who did, or at least affected to do, naughty things, wrote satirical verses, was supposed to know life, and in various ways exerted a baleful fascination over his fellow students. But, however the type of the college hero might vary, speech-making, debating or fine writing were the be-all and the end-all of college training, as in the world outside the colleges speech-making, debating or fine writing were the sole recognized signs and proofs of greatness. Physical force, dexterity, and

endurance, capacity for action, nerve, and will power went for little, or went for nothing, so far as public admiration was concerned. Statesmanship itself was perverted by eagerness to seek occasions for oratorical display. Men of business, men of affairs, men of prudence, moderation and real ability were crowded out of our legislative halls by shrill-voiced declaimers who could catch the ear of a nation given over to the lust of words. "Sir," once said Daniel Webster, bending those tremendous brows upon a young man afterwards renowned among the great attorney-generals of the United States, "sir, the curse of this country has been its eloquent men."

What was the reason for this state of things regarding the college ideals of a generation ago, so strongly contrasted with what we see to-day? In part, bad physiology, or the absence of anything that could be called physiology, was responsible for it; but in greater part I believe it was due to the transcendentalism and sentimentalism of the last quarter of the eighteenth and the first quarter of the nineteenth century, which had created false and pernicious opinions concerning personal character and conduct. There was more than indifference, there was contempt for physical prowess. A man who was known to be specially gifted in this way was thereby disparaged in public estimation. If he were known to make much of it, he was more likely to be despised. It was taken for granted that he could not be good for anything else. Brains and brawn were supposed to be developed in inverse ratio. Affected notions about intellectuality and spirituality had almost complete control of the popular thought. The only things to be admired were mind and soul. "Mere bigness" was a favorite phrase of contempt. Strength was believed to be closely akin to brutality. Danger, positive danger, to spirituality, if not also to morality, lay in physical force and exuberant vitality. The same notions perverted the ideals of womanly grace and beauty. Robust vigor, a hearty appetite, and a ruddy complexion would have been deemed incompatible with the function of the heroine of a popular novel or a sentimental poem, or even with the part of a belle in society. Languor and pallor were attractive, delicacy of frame and limb was admired.

The set of notions referred to were doubtless closely connected with the political ideas of those days. It was an era of transcendentalism in politics. Political mechanism was disparaged. The philosophy of the age declared that a virtuous people would of themselves

make a good government. On the other hand, it was impossible so to organize the public force as to give a people a government that should be better than themselves. The maxim, "A stream cannot rise higher than its source," was a conclusive answer to all pleas for the scientific treatment of political problems. There was an affectation of indifference towards size and numbers in national life. Quality, not quantity, was in the eyes of the men of those days the sole test of the worthiness and the greatness of a people. Mass went for nothing. "Mere bigness" was here, as in the case of the individual, a term of infinite contempt. I never shall forget the rebuke, not unkindly meant or harshly spoken, which I received from a distinguished leader of public thought for boasting in a boyish vein about the extent of my country and the greatness of its resources.

The indifference toward or the dislike of athletics a generation or two ago was also largely due to the religious ideas and feelings of the time. The body was but a shell, a prison in which the soul was confined, and against whose bars its aspirations continually beat and bruised themselves. In another image, the body was a wayside barn in which the weary pilgrim laid himself down to rest till break of day. The flesh was an incumbrance to the spirit, a clog, a burden, a snare. Men had been told to "keep the body under," and perchance this was thought to be an easier task if that body were small and weak.

I do not mean to be understood as asserting that in those days the *mens sana in corpore sano* was never spoken of, or that there was no formal teaching of the duty of preserving bodily health. Such precepts, however, could have little effect against general tendencies of thought and feeling; and even among the most intelligent teachers of those days there was manifest a strong dislike, a sharp shrinking from all dwelling upon the physical basis of life, as savoring of materialism. As to acknowledging the relationship of man to the other orders of animals, that would have filled the pious mind with horror. The philosophy of the time had, indeed, to admit that the soul was in a degree conditioned as to its manifestations, and especially as to its influence upon others, by purely physical causes. But the soul itself was a thing transcendent, supernal, and self-sufficing, which when released from the clogs of flesh became at once as perfect, pure, free, and strong as if its tenement, while in residence here, had been more worthy of it.

All the notions referred to, so prevalent and so potent in at least

this section of the United States forty or seventy years ago, have gone, and gone together. Other ideas better suited to inspire a progressive civilization have taken their place. In part this has been due to the decay of superstitions derived from primitive savagery, in part to the effects of positive teaching, in greater part still to further experience of life. Biology has done its share; political education has done its share; the war of secession wrought its appointed work in the same direction. The men of to-day are generally agreed that they are likely to live long enough to make it wise to think a hundred times how they shall live, to once thinking how they shall die. The caravansary idea of existence has been abandoned. Man is not a pilgrim but a citizen. He is going to tarry nights enough to make it worth while to patch up the tenement and even to look into the drainage. This world is a place to work in; activity and development, not suffering or self-repression, its law.

The present generation has witnessed a wonderful diminution of spiritual self-consciousness. Better physiology, coinciding with some changes in popular ideals, has driven away the notions about the flesh as an incumbrance, a clog, a burden, a snare. It is seen that morbid or even merely feeble conditions of body tend to generate delusions, selfishness and susceptibility to the worst impulses. This is seen to be the case not the less because of the saintliness and the heroic constancy of a million sufferers from pain and infirmity. Hearty physical force may, indeed, consist with vicious desires, but it does not favor them. On the contrary, it does in a way and in a degree tend to diminish and to uproot them. Vicious desires are at their worst in feebleness and in morbid conditions of body. The sounder a man is, the stronger he is, the less — other things equal — is he subject to what is bad and degrading; the more pleasure does he take in what is natural, healthful, and elevating. To a perfectly sane man physically life itself becomes a joy. The relish for it does not need to be stimulated by the spices of vicious indulgence any more than a healthy appetite needs to be stimulated by the spices of the cuisine.

The sociological investigations into the causes and manifestations of crime, so actively in progress during the past few years, have added much to our knowledge of human nature in its self-respecting and law-abiding phases. The popular idea of the criminal once was that of a powerful brute, whose offenses against society resulted from an excess of physical vigor not counterbalanced by moral and intel-

lectual forces. As a matter of fact, it is now known that the prisoners in our jails are, as a class, undersized and undervitalized creatures, often with a deficiency of coördination between their faculties, sometimes with a minimum of control over their own actions and little adaptability to social and industrial functions. In the remarkable, the truly admirable reformatory enterprise of Superintendent Brockway at Elmira, gymnastics, regulated exercise and manual training perform a most important part.

In the revolution of thought regarding bodily development and physical prowess Mr. Beecher exerted a great influence. He it was who led off in favor of Muscular Christianity. During the controversy on that subject which attracted so much attention just before the outbreak of our great war there was, we must admit, not a little of exaggeration on the part of the advocates of physical culture. Many wrote and spoke as if all evil was to be worked off in the gymnasium and on the race track; as if every vice of human nature would exude through the pores of the skin if only perspiration was sufficiently active and long enough maintained. But in spite of much that was crude and foolish, these men had got hold of a great truth, and they did not let go until they had drawn it out into the light. The war of secession, also, which has been adverted to, came in to produce a vast change in popular sentiments and ideals, as it showed how much nobler are strength of will, firmness of purpose, resolution to endure, and capacity for action than are the qualities of the speech-maker and the fine writer, which the nation had once agreed chiefly to admire.

With this change of opinion regarding physical force and physical training in the individual has come a notable change in the political philosophy of the age. Larger experience of affairs has shown the folly of disregarding political mechanism. It is seen that it is hard enough to keep the balance of forces upon the right side, if every safeguard be adopted, every device used, and every means employed to give a preference to those who stand for order, decency, and honesty in the community. We are all now for making the devil fight with the sun in his eyes, instead of at his back, and with the advantage of the ground against him, instead of in his favor. We no longer with confidence hold that a virtuous people will necessarily have a good government. On the contrary, we recognize that a people virtuous above the average may, through a bad organization of the public forces, be made to act

almost as if they were the most cowardly and dishonest of their kind, as did our forefathers under the confederation of 1781–87. It is true that the stream may not of itself rise higher than its source, but by machinery we can send a stream a good deal higher than its source, and can make it do there more of vitally essential work than could all the waters of old ocean lying at their level. Instead of discarding political mechanism, therefore, the men of to-day believe in political machinery, like that of the Australian ballot system. They have learned that by means of it they can help the cause of righteousness, and at times turn the scale against the forces of evil. They not only believe in political machinery, they even believe in political machines, actual structures of wood and glass like the patent ballot-box, as important agencies to defeat the baser elements of society.

Again, "mere bigness" has ceased to be a term of contempt as applied to nations. Power in a people has become a thing admired. It is felt that it is indeed a glorious thing to have a giant's strength; nor is it longer believed that the disposition to use strength tyrannously grows with the opportunity. The idea once prevalent that its possession leads to brutality and insolence has not been borne out by the history of our own people. As the United States have grown more powerful they have grown more peaceful. In the early days of the republic our petulance, irritability, and pugnacity made us a nuisance and a pest among the nations. Swagger and unbounded brag characterized our earlier diplomatic history; while the war with Mexico, the cheap talk about "manifest destiny," and the filibustering excursions of the middle of the century seemed to point us out as a bad neighbor to the strong and a bully towards the weak.

Doubtless the slave power was in some degree accountable for this; but in greater measure it was due to lack of confidence in ourselves. We were always afraid that we were not going to be respected and treated with due consideration. We felt that we were looked down upon because we were young and small. No sooner was the mighty demonstration made of our courage and military strength in that great Civil War which will always remain one of the marvels of human history, than all this fell away from the nation like some loathsome rheum of childhood. To-day Canada and Mexico repose under the shadow of our irresistible power without an apprehension of harm or wrong, and it is even difficult to secure from an over-lavish Congress appropriations sufficient to enable us to make a decent show of naval

power in the great harbors of the world. It is true we have recently suffered an apparent brief access of jingoism, owing to certain unfortunate political complications; but the readiness with which the affair with Chile was adjusted and the general applause with which our flag was hauled down from the government house at Hawaii showed how superficial and how partial was the infection.

After this long and tedious statement of changes in the ideas and sentiments of our people in the several directions indicated, is it too much to say that we have, as a community, got down upon a sound, practical, sensible, worldly basis of life, much more promising for morality, for a steadily progressive civilization, for enduring enthusiasms — aye, for worthy aspirations and a true spirituality — than the unreal, morbid transcendentalism and sentimentalism of three, two, or even only one generation ago?

Among the many things, good or bad as people may esteem them, resulting from the changes in feelings, views, and ideals which have been indicated, are two which especially concern colleges and college men: The first is the general disappearance, most fortunate as I esteem it, of the literary societies formerly so flourishing, and the decay of oratory, declamation, and debate, which to many once made up the main interest of college life. The second is the rapid growth of athletics, in which immense honor is given to young men because they are strong, swift, enduring, and brave; in which the blood of the whole community is stirred by physical contests among the picked youth of the land as once it was only stirred by tales of battle. This last it is which has given me my subject to-day.

That the general introduction of gymnastics into colleges is desirable, few will deny. Young men of the college age whose occupations are largely sedentary should be encouraged to undertake systematic and extended exercise in order to correct the faults of the study and recitation-room, to expand their frames, and to promote an active circulation. Amherst is entitled to the high honor of being the first of the American colleges to make ample and suitable provision for students' needs in this respect. In 1861, under the presidency of Dr. Stearns, a gymnasium, large and well equipped according to the standard of those days, was placed upon the campus; daily exercise was made compulsory upon students not excused for cause, and a certificated physician was made director of physical culture and lecturer on physiology and hygiene. Few colleges have fol-

lowed Amherst in making exercise other than in the form of military drill compulsory; but fewer still now fail to afford their pupils opportunity for voluntary gymnastics to the top of their bent. The improvement wrought by these means in the physique of our college students does not need to be shown statistically; it is manifest to the eye of the most casual observer who remembers the former state of things. So far, there is no ground of debate; difference of opinion only exists with respect to the competitive sports and games which have grown up out of the newly awakened interest in physical prowess.

And here let me propose a distinction between gymnastics and athletics, which will be carried through the remainder of this discussion. That distinction is not one based upon etymology, but has reference to current usage:

Gymnastics are for individual training and development, with health strongly in view. Athletics take the form of competition and contest; emulation is their moving spirit, glory the aim.

As thus distinguished in their primary objects, athletics differ from gymnastics in two respects: First, by specialization, as when a man chooses his line of work in athletics — whether that be pole-vaulting, or hurdle-racing, or rowing, or pitching in baseball, or playing a certain position in football — and thereafter devotes his energies to working himself up to the highest point of efficiency in that line; secondly, by excess in the amount of exercise over what would be required or would be performed without the introduction of the spirit of emulation. So great is this excess that it may not unfairly be said that athletics begin where gymnastics leave off.

The effects of specialization in athletics are too much a matter of detail to be entered upon here. Suffice it, in a word, to say that they are not unlike those of specialization in industry — good and evil being mingled with, in general, the preponderance largely on the side of the good. Specialization affords to bodily exercise a more direct object and creates a far more intense and sustained interest. Moreover, for the best specialized work it is well known that at least a fair all-round development is almost always a necessary condition.

The excess of exercise in athletics over gymnastics, as we have defined these terms, is it of good or of evil? Is it a gain, or mere waste, or a positive injury? Gymnastics are a means to the end of health and vigor. Athletics become an end in themselves. With exceptions too inconsiderable to be enumerated, the athlete competing

for championship honors takes more exercise, often far more exercise, than is required for health and strength with a view to the peaceful and industrial pursuits of life. Vital force is consumed, not created, by the final contests in which he engages, and not infrequently by the training to which he subjects himself in preparation for them. The consumption of vital force in athletics, if we contemplate young men who are fully grown or nearly so, may be considered as of two degrees: First, where vital force is consumed in competitive sports and games as it might be consumed in study or in the production of wealth, without impairing the constitution or diminishing the physical endowment upon the strength of which the subsequent work of life is to be done; secondly, where exercise is carried so far and such violent exertions are made that not merely is the current supply of vigor used up in this way, but the constitution is undermined and injuries are sustained or exhaustion induced which result in leaving the man less healthful or less powerful through the remaining years of his life.

Of the severer forms of athletic competition and contest, which injuriously affect the constitution and permanently impair the vital force, but one thing can be said, they are evil and only evil. No earthly object, except the saving of others' lives or the defense of one's country, could justify such destructive exercises and exertions. I am disposed, however, to believe that there has been much of exaggeration in the public mind regarding this matter, and that instances of permanent injury from athletics are fewer than popular rumor or maternal anxiety makes them to be. The life history of the leading football players of the past fifteen years, notwithstanding the frequency with which contusions, sprains, and even broken bones occur in the tremendous struggles of that mighty game, makes up a record of vitality and activity in the period succeeding graduation which proves that, despite the occasional outcries of the press, this form of athletic contest works little enduring injury among thoroughly trained competitors. The more serious accidents of football generally occur in the beginning of the season and among players who have not passed carefully through the hardening stages of practice. Boat-racing is probably fraught with much more of real peril to its participants; yet a distinguished English statistician, studying the life history of three hundred and twenty "Oxford oars," has reached the conclusion that, even after making due allowance for the fact that

these were all at the start picked men, this great body of athletes showed a vitality distinctly above the average. Yet when all has been said, it is still beyond question true that in the present intense interest in physical contests there is a real danger to be guarded against, especially among the younger and less experienced competitors.

Of those physical contests which result merely in the consumption at the time of current physical force which would otherwise, or might otherwise, be devoted to study, we cannot dispose so confidently and summarily. To those who hold to the good old notion — the excellent, virtuous notion — that all young men go to college to make themselves scholars, it is, indeed, a great trial to have to contemplate a state of things in which no inconsiderable proportion of students treat scholarship as an object distinctly subordinate to gladiatorial prowess, and who really graduate, if they graduate at all, in athletics as a major, with classics, or mathematics, or philosophy, or something else as a minor, or perhaps we should say a minimum. Certainly this presents a view of college life which would have filled with horror the founders and early governors of our New England colleges. And it needs to be said at the outset, in dealing with this subject, that there are hosts of young men coming to college whose circumstances and means and views and plans of life are such that they cannot afford to treat their educational privileges in this way; who if they "go into athletics," in the accepted sense of that phrase, will sacrifice the one opportunity offered them; whose presence with their classes means a degree of sacrifice and self-denial on the part of parents and friends which would make it little less than profanation to waste an hour of the time which has been purchased at such a price. And yet, with due consideration for the rights and interests of students like these, college athletics confessedly as an end in themselves are not wholly of evil. Several things have to be considered before we are fairly in a position to pass judgment upon them.

The least important thing that can be said in their favor is that they afford enjoyment to vast numbers throughout the land; yet, for one, I would not treat even this consideration as unworthy of respect. The college athletics of to-day do wonderfully light-up the life of our people. The great recurring contests and the intermediate practice games and friendly competitions of the several teams give acute delight to a large and increasing constituency. This nation has long

shown the painful need of more in the way of popular amusement, of more that shall call men in great throngs out into the open air, of more that shall arouse an interest in something besides money-getting or professional preferment. In these respects college athletics have made an important contribution within the past few years. The marvelous rapidity with which football has spread and is still spreading throughout the Western and Southern States shows how eagerly it is welcomed as a relief to the monotony of life.

A stronger plea for college athletics is made when it is urged that they result in stimulating an interest in gymnastics among those students who do not engage in competitive contests, and also throughout the general community. The effect of this may easily be exaggerated. There is many a weak-kneed collegian who crawls out to witness the great baseball or football game of the year, looks on with intense delight, cheers the victors, if of his own side, as loudly as his limited lung capacity will permit, and then, when all is over, crawls back again to his room without so much as a conscious impulse to improve his own bodily condition. Yet it is certain that the cause indicated has an influence, and an influence not inconsiderable, for good. Admiration for manly prowess and the contemplation of fine physical development cannot fail to secure a much wider cultivation of gymnastics than would take place without it.

But, again, it must be said that the favorite athletics of to-day are, in great measure, such as call for more than mere strength and swiftness. They demand also steadiness of nerve, quickness of apprehension, coolness, resourcefulness, self-knowledge, self-reliance. Further still, they often demand of the contestants the ability to work with others, power of combination, readiness to subordinate individual impulses, selfish desires, and even personal credit to a common end. These are all qualities useful in any profession; in some professions they are of the highest value; and it cannot be gainsaid that it is the normal effect of certain kinds of athletic sports to develop these qualities among the contestants, as well as to afford impressive examples to the minds of the spectators. So genuine does this advantage appear to me that were I superintendent of the academy at West Point I should encourage the game of football among the cadets as a military exercise of no mean importance. It is the opinion of most educated Englishmen that the cultivation of this sport in the public schools of that country has had not a little to do with the

courage, address, and energy with which the graduates of Rugby, Eton, and Harrow have made their way through dangers and over difficulties in all quarters of the globe.

The last consideration which I would adduce to show that what is sacrificed in athletics is not all lost is that in the competitive contests of our colleges something akin to patriotism and public spirit is developed, with results, on the whole, of good. It is true that young men often carry their manifestations of zeal and devotion to their colleges too far. Yet, both as counteracting the selfish, individualistic tendencies of the age and as an antidote to the *nil admirari* affectations of our older colleges, it is a good thing that the body of students should now and then be stirred to the very depths of their souls; that they should have something outside themselves to care for; that they should learn to love passionately, even if a little animosity towards rivals must mingle with their patriotic fervor; that they should at times palpitate with hope and fear and anxiety in the view of objects which can bring to them personally neither gain nor loss.

Of the special evils of college athletics as now cultivated I do not purpose to speak at length. Some of those at present most clearly perceived are chiefly due to newness and rawness, and will of themselves disappear, in whole or in part, with time and further experience. Faults of method have yet to be eliminated; the traditions of the several games have yet to be created. For example, that regard for fair play, that respect for the rights of an opponent, that deference to the decisions of the umpire, so conspicuous in England, have there been the work of generations. They cannot be built up in a day with us. Yet our people are wonderfully quick to learn, especially to learn everything that conduces to harmony and adjustment of claims; the American is eminently and preëminently a political animal; and nowhere in the world are great crowds so orderly, peaceable, and good-natured as here.

One of the first things which should receive the attention of all lovers of fair play is the complete abolition, once and for all, of the unsportsmanlike system of organized cheering by great bodies of collegians grouped together for the purpose, with chosen youths of peculiar gesticulatory graces and preëminent lung power to start the movement and "deacon off" the shouting. Such a line of conduct, thoughtlessly resorted to in the heat of partisanship, is unworthy of educated men. It is unfair to the visiting team, who by all the laws of courtesy are

entitled to special consideration. How much more pleasing to the spectators, how much more creditable to the home college, if the stranger for the while within its gates were to be treated with something like the grace of antique chivalry!

Again, we may confidently expect that the machinery for carrying on sports and contests will undergo a steady improvement. We see a remarkable instance of the virtue of this in the appointment of the second umpire at football, which at once did away with certain tendencies that had threatened to make the game impossible. Audiences, too, must be trained to appreciate the finer points, to applaud good work by whomsoever done, and to be as virtuous as a Greek chorus, to the end that the game may be played by the players and not by the spectators. The coöperation of alumni is also to be invoked to give wisdom, weight, and temper to the action of the undergraduate bodies. Not least — nay, perhaps hardest of all — Faculties are to be educated, to avoid intermeddling and petty dictation on the one hand, and to sustain the claims of scholarship and enforce the right discipline of college on the other.

The last clause suggests one of the most important considerations related to the subject. Granting that something, and that not a little, of scholarship must be sacrificed if athletics are to be continued on anything approaching their present scale, may we yet believe that it is practicable to insist upon the requirement of at least respectable standing in the case of all who participate in intercollegiate contests? I believe that this can be done without interfering with the general movement, provided college Faculties are true to themselves, fair, frank and firm in dealing with the student bodies, and thoroughly honest in their treatment of the subject. I would not be understood to intimate that a certain amount of good sense would be out of place.

Perhaps it will not be taken amiss if I allude here to the results of my own observation in a sister university regarding which it has been my fortune to know more than I do concerning Harvard. At Yale, and especially in the scientific department, the Faculty appear to me to have been highly successful in preventing a total sacrifice of scholarly standing to intercollegiate sports. But a small proportion of the champion athletes in that university, a smaller proportion still in the scientific school, have been men at or near the foot of their classes — the sort of men who have to be hounded, threatened, and repeatedly conditioned in order to keep them up to the mark. Not a few

of them, from Kennedy to Hartwell, have been high up on the roll of academic honor. I attribute this excellent result to the thoroughly good understanding between students and the Faculty, to the absence of petty prescriptions and of all intermeddling as to details, and to the frankness with which the few positive requirements relating to the subject are stated and enforced.

I fear there is little in what has been here said to give comfort to those who distrust and dislike college athletics — little which intimates the opinion that the athleticism of to-day is only a reaction after the former total neglect of gymnastics, or a mere passing passion among our youth. But if we concede that these exercises and contests are to hold their place in American life, is there no stopping place, no point at which college authorities or the young men themselves, on their own motion, in their own discretion, for their own good, can say, "Thus far and no farther"?

I answer yes; there is such a natural stopping place. It is at the doors of the professional school. Among young men in the course of education, athletics should belong to the college stage; gymnastics to all stages. Whether this shall be done by regulation, or be left to the operation of forces working upon the minds of the individuals concerned, I believe the result indicated will, in either case, be reached. Already the undergraduate principle is widely though irregularly recognized; and the movement of opinion is still clearly in progress in this direction. Here at Harvard you have seen many a renowned champion put off athletics as he entered the law school or the medical school. The rule should be made of universal application; and it will require but a little more of discussion, but a little higher education of student-opinion, to bring this about. In and after the professional school, whether that be a school of law, of medicine, of divinity, or of technology, there should be no representative teams. The principle of competition and championship should be dropped. Individuals should continue, at their pleasure, to play tennis or cricket or football with their classes, with private clubs, or in town and county matches; or if teams be formed in such schools they should not be regarded as carrying the honor of their institutions around with them. Such teams should not expect victory. They should play for exercise and for the fun of the thing, and should accept their inevitable beating with serenity and good nature, recognizing the fact that since they have taken up the serious work of pro-

fessional preparation for life they no longer have the time or the strength at command to make and keep them champions.

There is one remaining question regarding the athleticism of today, which I feel myself so little qualified to discuss that I did not even allude to it while enumerating the things that might be said in favor of competitive sports, or at least in deprecation of the hostile criticisms directed upon them, which, however, here in closing I would fain propose to your sounder judgment and keener thought.

It is whether the college athletics, which so many approve and so many condemn, have not after all a deeper significance — whether this remarkable outburst of enthusiasm for physical development and for the perfecting of the human body is not related, perhaps vitally and intimately, to the growth of a feeling for art in this new land of ours. No classical scholar will for a moment admit that it was an accidental coincidence that the nation of the Old World which pursued athletics with the most passionate eagerness, which showered honors upon the victor in running or in wrestling not inferior to those which it gave to the author of an accepted tragedy — that nation whose tribes came by long and perilous journeys over stormy seas to witness the great athletic competitions by the banks of the Alpheus or on the Crissæan plain — was the same nation which carried the arts, and especially the plastic arts, to the highest point of perfection ever attained.

If, indeed, there is believed to have been a vital connection between these seemingly diverse manifestations of Grecian life, who shall say that the remarkable enthusiasm for physical training and the intense interest in athletic contests which have been so suddenly developed in our country may not be clearly seen a generation hence to have accompanied, and that through no accidental association, the elevation of art to a far higher and nobler place than it had before occupied in the thoughts and affections of our people? The life class is the true school of the artist. The greatest of all who bear that name have been men who revered the human form, made it their chief study, and found in it their highest delight. If in truth this sublime passion is taking possession of the nation, who shall estimate at a price the worth of that inspiration? The vision of the Apollo may yet rise to the view of thousands out and up from the arena at Springfield, as erst it rose before the thronging multitudes of Olympia.

# *THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

By DWIGHT PORTER, Ph.B., Associate Professor of Hydraulic Engineering.[1]

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This laboratory has been arranged and equipped upon an extensive scale for experimental researches and practical tests in hydraulics. The apparatus is used by the students of nearly all the engineering courses in regular laboratory exercises, during which they work in sections no larger than strictly necessary for conducting the particular experiment in hand. Such work is designed to give the students a practical demonstration of laws with which they have become familiar in a theoretical way only, to acquaint them with the appearance and behavior of certain standard forms of apparatus, and to teach them the methods and precautions commonly necessary in hydraulic experiments. The time allotted to any one variety of work is what seems sufficient fairly to attain the above ends, and no more, it not being proposed in class exercises to make the young men adepts, nor in general to achieve results in those exercises of especial scientific importance. In connection with thesis work, or the studies of post-graduate students, special apparatus is every year devised and installed suited to original investigations and to the securing of results of permanent interest and value.

The space devoted to the hydraulic laboratory covers about 30 x 50 feet on each of the two lower floors of the engineering building. The general arrangement of pipes and apparatus on the second floor of the laboratory is shown by the plan (Figure 1), and the view (Figure 2). The primary source of water supply is the city main, but it is rarely that draught is made directly upon this during an experiment, water being directly supplied from pumps, which in turn draw from a large receiving pit sunk below the basement floor, the discharge from all experiments finding its way to the pit and thus being used over and over. Several pumps are in use — steam, rotary, and centrifugal — sup-

[1] Abstract of paper read June 14, 1893, at the 12th annual meeting of the New England Water Works Association.

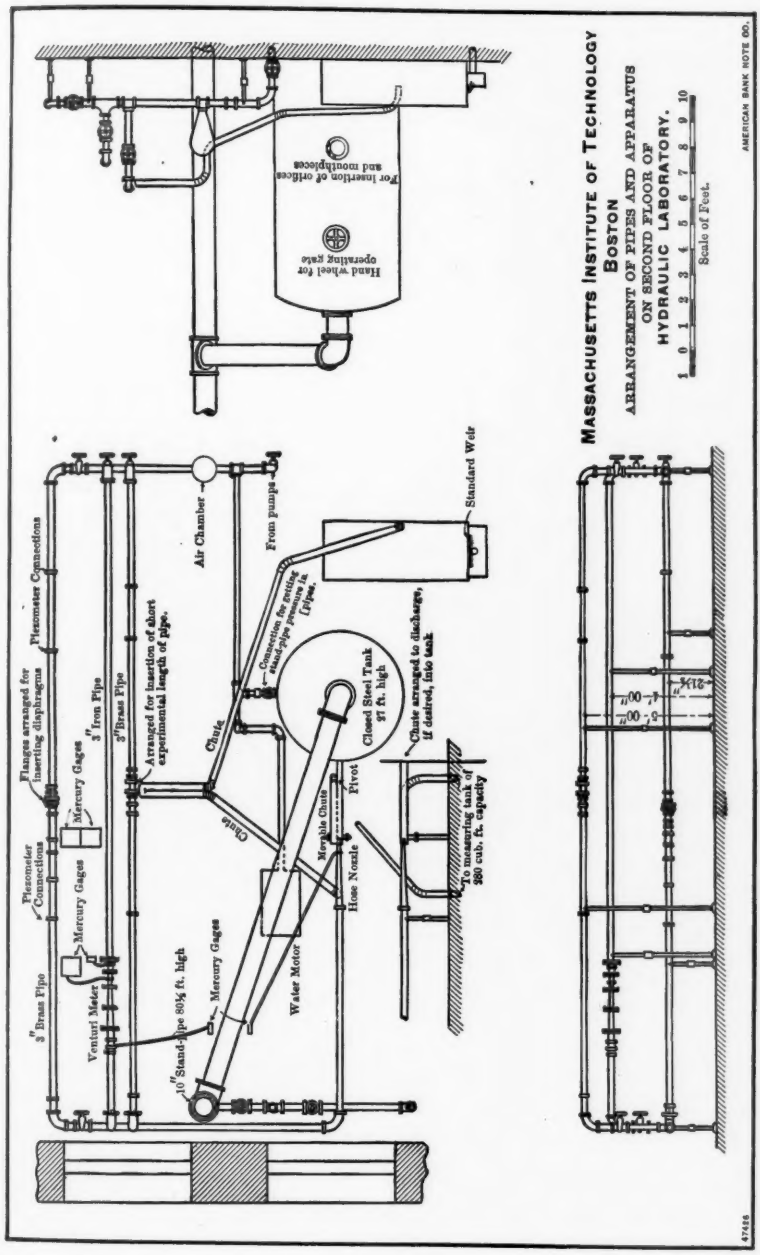

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
BOSTON
ARRANGEMENT OF PIPES AND APPARATUS
ON SECOND FLOOR OF
HYDRAULIC LABORATORY.
Scale of Feet.
AMERICAN BANK NOTE CO.
Hand wheel for operating gate
For insertion of orifices and mouthpieces
Piezometer Connections
Flanges arranged for inserting diaphragms
Mercury Gages
3" Iron Pipe
3" Brass Pipe
Arranged for insertion of short experimental length of pipe.
Air Chamber
From pumps
Standard Weir
Connection for getting velocity pressure in pipes.
Chute
Closed Steel Tank 21 ft. high
Chute arranged to discharge, if desired, into tank
To measuring tank of 300 cub. ft. capacity
Pivot
Movable Chute
Hose Nozzle
Water Motor
Venturi Meter
10" Stand-pipe 80½ ft. high
3" Brass Pipe
Piezometer Connections
Mercury Gages
Mercury Gages
Mercury Gages
47486

FIG. 1.

plying the different apparatus. In order to secure a more constant pressure than that from the pumps, for certain kinds of experiments, a ten-inch standpipe, shown in plan in Figure 1, eighty feet high, has been built, reaching to the top of the building. The supply to this from the pumps may be so regulated by valves and overflows conveniently arranged on each floor that the head shall be kept at any desired point during an experiment, with a fluctuation of scarcely a hundredth of a foot. Many of the pieces of apparatus have been so arranged that they can be run at will under pressure either from the standpipe or directly from the pumps.

An important feature of the plant is a closed steel tank, five feet in diameter and twenty-seven feet high (Figures 1, 2, and 4) extending from the basement floor upward through two stories. It is connected at top and at bottom with the standpipe previously mentioned, and at four points on each floor is arranged for the insertion of orifices, free or submerged, mouthpieces and other fittings, and for connections with motors and experimental pipes. It is fitted with hydraulic gates so planned that an orifice, for example, may be quickly exchanged for another without the necessity of drawing down the water in the tank.

For certain experiments on the flow of water through pipes three lines of three-inch pipe (Figures 1 and 2) have been erected. One of these is of iron, with a Venturi meter, shown on the right of the foreground of Figure 2, inserted in its course; the other two are of brass, very carefully made, with piezometer connections of approved form at sundry points. One of the brass pipes is arranged for the insertion of diaphragms with orifices of various sizes, and the other for the insertion of short experimental pieces of pipe provided with side orifices, branches, or other devices. The discharge from the various pipe lines passes finally through a hose nozzle, with pressure-gauge connection to be used in determining the coefficient of discharge. The nozzle discharges (Figure 1) into a movable double chute, through one branch of which the flow may be wasted until it is desired to begin an experiment, when the other branch may instantly be thrown into the path of the jet and the water directed through the floor into a measuring tank beneath.

For delicate observations upon the velocity at any given point in flowing water, the laboratory contains three different instruments (Figure 3) embodying the principle of the Pitot tube. Two of these,

for use, respectively, in jets from nozzles and in streams flowing under pressure through pipes, are the property of Mr. John R. Freeman, by whom they have kindly been placed at the command of the Institute. The third, for jets from standard orifices, has been designed especially to use on the large tank which has been described, and one in use is shown by Figure 4. In each case the pressure of the flowing water due to its velocity is transmitted through a minute orifice and a connecting tube to a mercury gauge, the reading of which indicates the velocity at the tip of the tube. A simple attachment to the last-mentioned of these devices has permitted measuring the shape of the jet and the size of the contracted vein with the greatest nicety.

For measuring the quantity of water discharged during experiments the common method employed is that of weighing, the temperature of the water being at the same time observed. Thus, in determining the coefficient of discharge of standard orifices, the flow from the orifice passes into a large cask, with ample discharge pipe and quick acting valve at the bottom, and thence into another and similar cask underneath resting directly upon scales. The upper cask serves for temporary storage while the contents of the lower one are being weighed and discharged. By this means, with casks of moderate size, it is not difficult to weigh continuously at the rate of 40,000 or 50,000 pounds of water per hour. Again, the discharge from experiments on the second floor may be diverted through chutes to any one of several measuring devices on the floor below. One of the most important of these is a cylindrical steel tank six feet in diameter and ten feet high, capable of holding some 280 cubic feet of water. This tank is conveniently placed for drawing off and weighing the contents, and is by this means calibrated. In order to determine the quantity discharged into the tank in any experiment it is then necessary only to read a glass gauge attached to the tank and provided with sliding sight and vernier. For more indirect determinations of quantities of water the laboratory contains a number of weirs of different lengths, up to four feet, a calibrated orifice tank, Venturi and other water-meters, nozzles, and standard orifices.

The pieces of apparatus which have been mentioned will suggest to the mind a great variety of experimental work to which they are suited, and to much of which they have actually been applied. The laboratory further contains a Pelton water-motor, a small Swain turbine, a Douglas hydraulic ram, and a variety of dynamometers, mer-

cury gauges, piezometer fittings, etc. Figure 5 is a view of a Swain turbine being tested by students. There have also been placed in the laboratory a large number of finely constructed orifices and metal pieces of sundry descriptions which were used many years ago by Uriah Boyden and James B. Francis in their famous experimental work at Lowell.

The laboratory has been designed with a view to extensive further developments, important advances in which are likely to be made every year. It has been steadily taxed to its utmost capacity, both for regular class exercises and for thesis work, and fully commends itself as a substantial aid in engineering education.

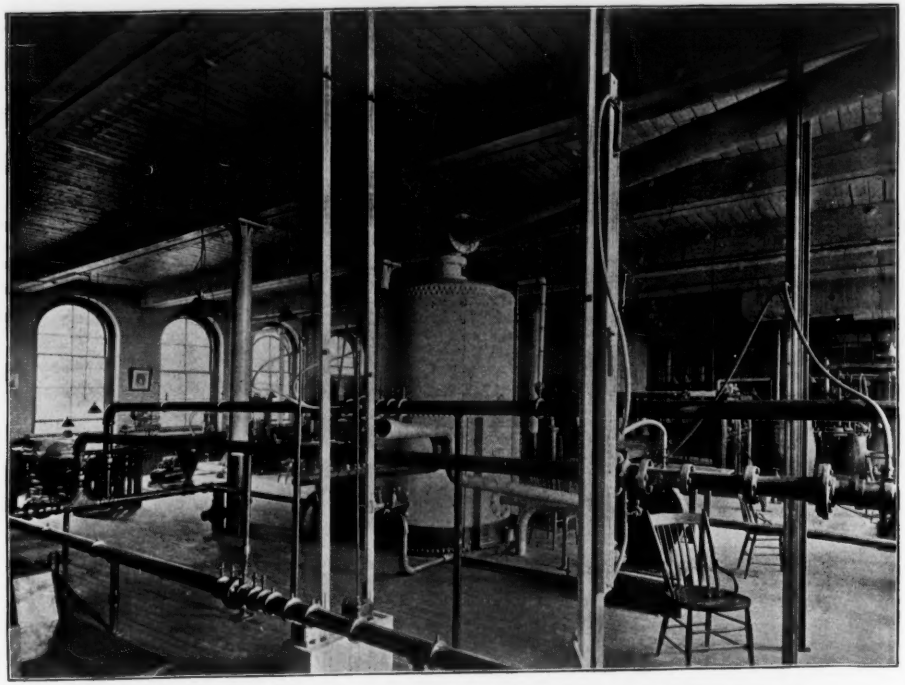


FIG. 2. VIEW OF SECOND FLOOR OF HYDRAULIC LABORATORY.

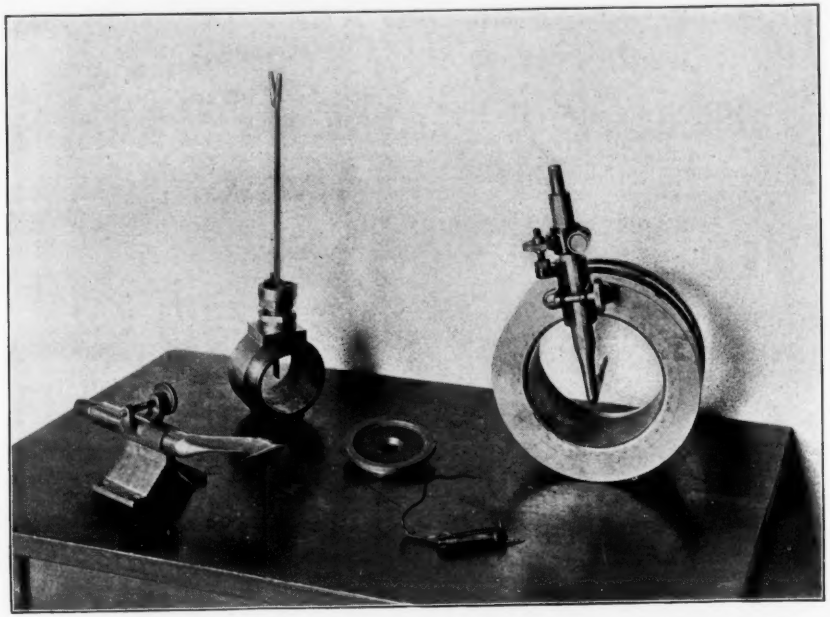


FIG. 3. FORMS OF PITOT TUBES USED IN EXPERIMENTS ON THE VELOCITIES IN FLOWING WATER.

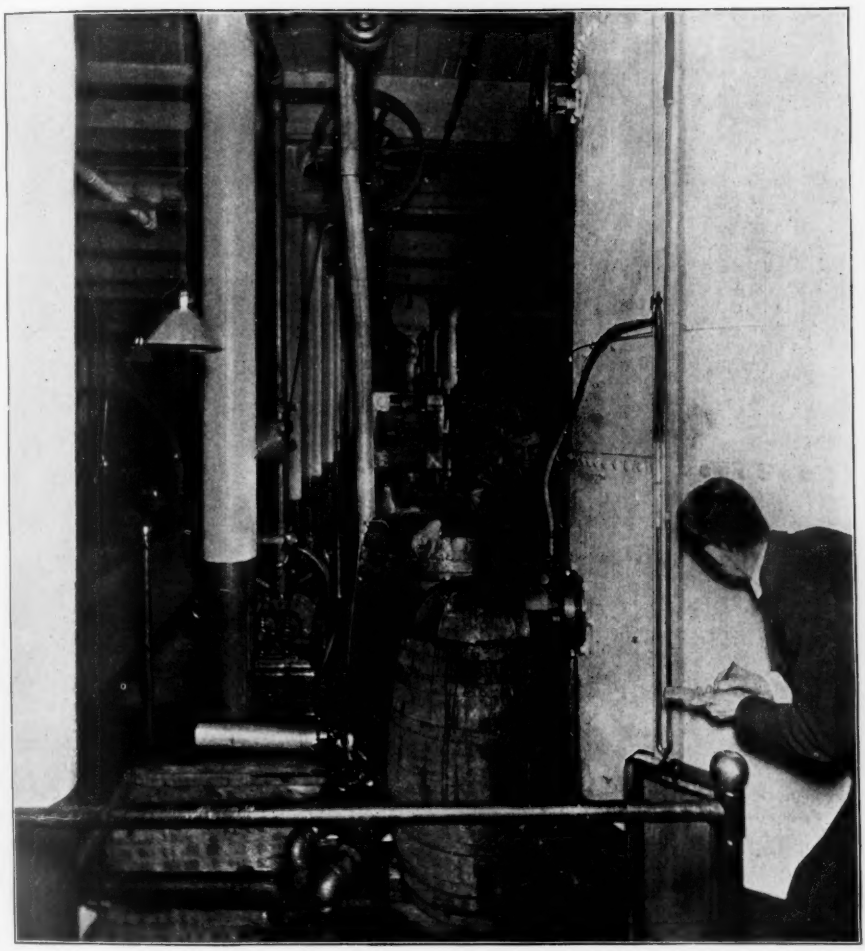


FIG. 4. STUDYING VARIATIONS OF VELOCITY IN A JET FROM A STANDARD ORIFICE BY MEANS OF A PITOT TUBE.

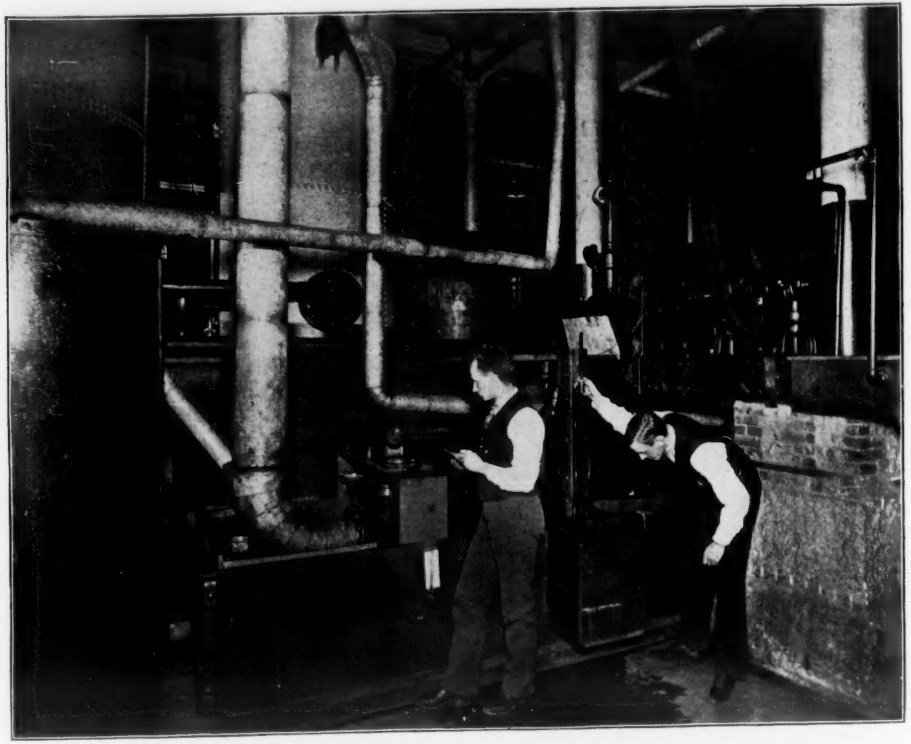


FIG. 5. STUDENTS TESTING A SWAIN TURBINE.

# *ADDITIONAL NOTES ON THE PRISMATIC STADIA-TELESCOPE.*[1]

By ROBERT H. RICHARDS, S.B.

Received May 3, 1893.

In October, 1891, I read a paper before the American Institute of Mining Engineers[2] on a "Hand-Telescope for Stadia-Work," and promised to report at an early date some results showing the degree of accuracy attained with the instrument. I am now able to report on these results and also on certain improvements that I have made in the target since the first paper was read.

I may say that I prefer the title "Prismatic Stadia-Telescope" to that used in my earlier paper, for while the instrument can be used with perfect satisfaction for short sights up to, say, 300 to 500 feet when held in the hand, it is impossible to read much longer distances without the use of a tripod as a steady support for the instrument.

Results are here given upon four combinations of prism and telescope.

No. 1. A telescope made by Alvan Clark & Sons, 3-inch objective, 28 inches focal length, magnifying 60 diameters, the prism covering half the objective:

| Feet measured by tape. | Reading of the rod. | Distance reduced to feet. | Reading of rod proportional to 100 feet. |
|---|---|---|---|
| 127.66 | 1.1825 | 100 | .92629 |
| 211.35 | 1.9585 | 100 | .92666 |
| 326.59 | 3.0265 | 100 | .92669 |
| 484.88 | 4.4925 | 100 | .92652 |
| 606.91 | 5.6225 | 100 | .92641 |
| | | | Average, .92651 |

[1] A paper read at the Montreal Meeting of the American Institute of Mining Engineers, February 21, 1893.

[2] Read also before the Society of Arts; see Technology Quarterly, 5, 56.

The value of this prism, therefore, is .92651 feet on the rod for 100 feet of distance, or 1 foot on the rod corresponds to 107.931 feet of distance.

No. 2. A Bardou telescope having a 1-incn objective, magnifying 20 diameters, and a prism covering half the objective:

| Feet measured by tape. | Reading of the rod. | Distance reduced to feet. | Reading of rod proportional to 100 feet. |
|---|---|---|---|
| 127.66 | 1.1825 | 100 | .92628 |
| 211.35 | 1.9585 | 100 | .92666 |
| 326.59 | 3.0265 | 100 | .92608 |
| 484.88 | 4.4875 | 100 | .92548 |
| 1613.15 | 14.950 | 100 | .92675 |
| | | | Average, .92634 |

This average is obtained by discarding the fourth reading, which is manifestly not quite as accurate as the others.

The value of this prism, therefore, is .92634 feet on the rod for 100 feet of distance, or 1 foot on the rod corresponds to 107.97 feet of distance.

No. 3. A Bardou telescope having a 1-inch objective, magnifying 20 diameters, and a prism covering half the objective:

| Feet measured by tape. | Reading of the rod. | Distance reduced to feet. | Reading of rod proportional to 100 feet. |
|---|---|---|---|
| 127.66 | .8345 | 100 | .65368 |
| 211.35 | 1.3815 | 100 | .65365 |
| 326.59 | 2.1325 | 100 | .65289 |
| 484.88 | 3.1695 | 100 | .65366 |
| | | | Average, .65366 |

This average was obtained by discarding the third reading, which is obviously an imperfect observation.

The value of this prism is .65366 feet on the rod for 100 feet of distance, or 1 foot on the rod corresponds to 152.29 feet of distance.

No. 4. A small cheap telescope having a $\frac{3}{4}$-inch objective, magnifying 10 diameters, and a double prism divided in halves, one half being set with the edge up and the other half with the edge down,

giving, therefore, two bent rays instead of the usual arrangement of one bent and one direct ray:

| Feet measured by tape. | Reading of the rod. | Distance reduced to feet. | Reading of rod proportional to 100 feet. |
|---|---|---|---|
| 15.97 | .5 | 100 | 3.1308 |
| 31.99 | 1.0 | 100 | 3.1259 |
| 47.94 | 1.5 | 100 | 3.1289 |
| 63.95 | 2.0 | 100 | 3.1279 |
| 79.94 | 2.5 | 100 | 3.1273 |
| 95.99 | 3.0 | 100 | 3.1242 |
| | | | Average, 3 1275 |

The value of this prism, therefore, is 3.1275 feet on the rod for 100 feet of distance, or 1 foot on the rod corresponds to 31.974 feet of distance.

The self-reading rod which has been devised for use with this prismatic stadia-telescope, and which gives perfectly satisfactory readings, is shown in Figure 1. Figure 2 shows the same rod while being read; the reading in this case is 234 feet. This rod has three stages of graduation; the largest space, namely, the space between the large numbers, 0, 1, 2, 3, etc., represents 50 feet; the single notch of the main scale, 10 feet; and the vernier which is brought down by the prism into juxtaposition with the main scale divides that space into units of 2 feet, while by the eye one can further subdivide to single feet.

Now, referring to the prisms tested as above, for No. 4, the three graduations of the rod that will be found best are 25 feet, 5 feet, and 1 foot. Such a target can be read easily when the instrument is held in the hand at 400 to 500 feet distance.

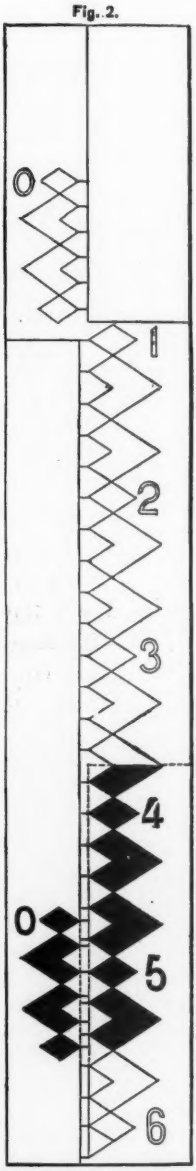
For prism No. 3, if the graduations of the target represent 50 feet, 10 feet, and 2 feet respectively, the target is a strong-reading one at 500 feet, but requires a tripod for the instrument. It can be read even at 700 feet, but is not strong at that distance.

For prism No. 2, the graduations of the target should be respectively 50 feet, 10 feet, and 2 feet; it will then give a strong reading at 800 feet from the tripod. If a 30-diameter telescope be substituted for the 20, the target will be good at 1,100 or 1,200 feet.

Fig. 1

SELF-READING TARGET AS SEEN BY THE EYE

Fig. 2.




SELF-READING TARGET AS SEEN THROUGH THE PRISM

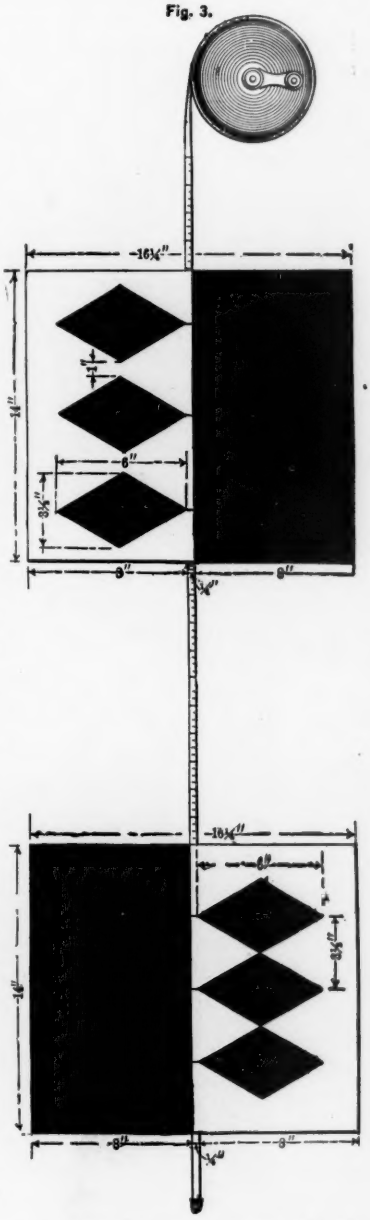
For prism No. 1, the graduations of the target should be respectively 50 feet, 10 feet, and 2 feet, and this target can be read at a distance of 1,500 feet or more. The rod, however, would be inconveniently long.

When the distances to be read are much greater than 1,000 feet, the two sliding-targets upon the tape (Figure 3) will be found more satisfactory. The coincidence here is between the two center diamonds, a very strong reading. (See Figure 4.) These targets may be read at distances varying with their size. A target of the dimensions given in Figure 3 can be read easily at 1,600 feet with prisms No. 2 and No. 3. It can probably be easily read to 2,500 feet with a 30-diameter telescope having a No. 2 prism, and probably also at a distance of 3,000 to 4,000 feet with a No. 1 prism.

If the sun be shining bright and hot, creating much flicker in the atmosphere, the instrument becomes unreliable for long distances. On the other hand, it breaks down for any distance, either long or short, if one target is exposed to bright sunlight, which causes a contraction of the pupil, while the other is in dark shade. On dull, cloudy days, the target may be read with great nicety at extreme distances.

The advantages claimed for this

Fig. 3.




TAPE-TARGETS AS SEEN BY THE EYE.

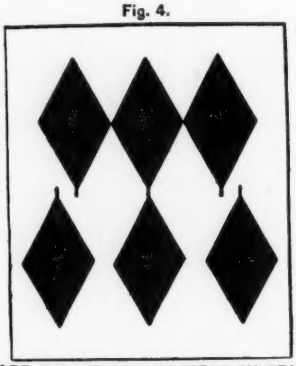
prismatic stadia-telescope, as compared with the usual forms read by spider-lines in the telescope, are:

1. The starting-point for the measurement is within the prism, instead of being at an imaginary point some distance in front of the objective.

2. Only one observation is required for measuring a distance, and there is therefore only one personal equation instead of two.

3. The portion of the target which is to be read is the only part that is distinct, it being unnecessary to hunt for the reading. (See Figure 2.)

Fig. 4.



TAPE-TARGETS BEING READ BY PRISM.

4. The reading is made in two ways, by convergence of the immediate points read and by double divergence of the contiguous points above and below. With the spider-webs, convergence only is used.

5. It would seem as if the probable error should be less where two diamond-points are juxtaposed than where a portion of the target is hidden by the thickness of the spider-line.

6. The prismatic stadia-telescope can be used from the hand for short distances, which is impossible with the spider-web instruments.

7. Long distances can be satisfactorily measured by the tape and sliding-targets, which is impossible with the spider-web.

# *ON METHODS USED AND RESULTS OBTAINED IN MAKING GERMICIDAL-EFFICIENCY TESTS OF A DISINFECTANT FOR USE IN RAILWAY SANITATION.*

By WILLIAM T. SEDGWICK, Ph.D.

Received August 18, 1893.

The arrival of Asiatic cholera in the harbor of New York in the autumn of 1892 directed general attention to matters of public sanitation. The disease was brought upon steamships, and much of the alarm that was felt was due to the knowledge that cholera might be carried all over the land by the railroads. The importance of railway sanitation had long been known to experts, and the presence of cholera at our doors served to inform the public. Fortunately, in 1892, the disease was confined to New York.

Recognizing the probability of a recurrence of the danger and the possibility of a more serious invasion in 1893, and anxious to be ready for any emergency, the officers of the Pennsylvania Railroad Company determined to have thoroughly tested, with respect to its efficiency or germicidal power, a disinfectant of their own manufacture, which, since 1885, they have been using in their cars, closets, urinals, passenger stations, freight-houses, shops, etc., or wherever a liquid disinfectant is applicable upon a railway system. The extent and public importance of such disinfection may be realized from the fact that this company operates altogether nearly 8,000 miles of railway. It forms one of the principal avenues of communication between the principal seaports of the United States and the great West. It carries over its lines yearly many thousands of immigrants, and directly connects one with another the largest cities in the United States. It is therefore held to be one of the most important railway systems in America; and it has a reputation for careful and scientific administration.

I am informed by Dr. C. B. Dudley, Chief of its Chemical Department, that chemical studies on commercial disinfectants by this road began as early as 1880, and in 1884 these studies culminated in the

thorough examination of some twenty-six commercial disinfectants. In view of the multiplicity of materials offered in the market as disinfectants, and the very high price charged for many worthless compounds, it was decided to embody the results of all these studies in a specification for a disinfectant to be made for the use of the road. This specification was issued in February, 1885. A few years later, when the work of the Committee on Disinfectants of the American Public Health Association became available, this specification was revised accordingly, and the so-called P. R. R. Standard Disinfectant was brought up to date.

The disinfectant submitted to me for tests of its germicidal power was said to consist of a concentrated solution of chloride of zinc, chloride of copper, and bichloride of mercury, with a few drops of terebene. The terebene was added as a telltale, to inform the officers whether the disinfectant had been faithfully used, rather than as a disinfectant. I was also informed that the disinfectant contains one part in five hundred of bichloride of mercury and a little over 45 per cent. of chloride of zinc. The chloride of copper was added because a little copper salt was desired to fix sulphuretted hydrogen, and the chloride of zinc solution was made very strong on account of the well-known deodorizing properties of this material.

I am also informed by Dr. Dudley that this disinfectant is made by the railroad company, for its own use, under the supervision of the officers of its laboratory. Old battery zincs which are no longer useful in the batteries, muriatic acid, sulphate of copper, common salt, and bichloride of mercury are used in its manufacture. The actual cost of the disinfecting material in an eight-ounce bottle is about two and one half cents. The material is distributed to the service in wooden boxes, holding twenty-four bottles each, and in barrels. If these boxes and bottles are returned, the real cost to the different parts of the service is the figure given above. If the bottles are broken and the boxes destroyed the cost is somewhat greater. In barrels which are not returned the cost is somewhat less than in bottles, no labor being required for bottling. There were made and used on the whole Pennsylvania railway system during the year 1892 366 gross of eight-ounce bottles and 69 fifty-gallon barrels.

The specifications to which the disinfectant must conform are given as follows:

"Disinfectant for the use of the Pennsylvania Railroad Company

BRARY



will consist of a neutral solution of the normal chlorides of copper and zinc and mercuric chloride put up in eight (8) ounce bottles and securely corked. Each bottle should contain 2,400 grains of zincic chloride, 120 grains of cupric chloride, 10.5 grains of mercuric chloride, and ten drops of a mixture of equal parts of terebene and turpentine."

The bottles must have pasted upon them the following "Directions for Use," a perusal of which will convey a good idea of the scope and the importance to the community of efficient railway sanitation:

DIRECTIONS FOR USE.

FOR USE ON CARS. — Empty the contents of this bottle into about one quart of water. With a sponge or waste, wash with the liquid all parts of the urinal, seat, and hopper, and the floor adjacent to them in the closet, allowing some of the liquid to run down the urinal pipes. The same solution should be used on the floors and woodwork of the whole car whenever washing with disinfectant is necessary. The carpets and plush of an infected car should not be treated with disinfectant, but should be fumigated instead.

FOR CLEANING PRIVIES, CLOSETS, ETC. — Empty the contents of this bottle into about one quart of water, and use as above. The disinfectant acts slowly on lead, tin, copper, brass, iron, etc., and it is not advisable to allow it to stand in the basins or traps. In the vault, use the disinfectant full strength, not less than half a dozen bottles at once, but it is better to disinfect privy vaults with crushed sulphate of copper, or chloride of lime, sprinkled freely over the mass.

FOR REMOVING BAD ODORS. — Empty the contents of this bottle into about one quart of water, and sprinkle the liquid in the place from which the odors arise; also saturate a towel, or other fibrous substance, with the liquid and hang it in the place from which it is desired to remove the odors. For use on towels, etc., a disinfectant without color can be furnished if desired.

IN CASES OF DIPHTHERIA, SCARLET, TYPHOID, AND TYPHUS FEVERS, CHOLERA, DYSENTERY, CONSUMPTION, ETC. — Place a little of the disinfectant, full strength, in the vessel which receives the excrement, or vomit, or throat discharge, and pour more of the disinfectant on the discharge after it has been received in the vessel. If the discharge soils the floor or furniture wash these soiled spots with the disinfectant mixed with water as above. Soiled bed and body linen, rags, or handkerchiefs used to receive discharges, and soiled clothing should be burned, or soaked in disinfectant diluted as above, for four hours and then rinsed with water.

FOR THE DEAD, WHERE DISINFECTANT IS NECESSARY. — Wrap the body in a sheet thoroughly saturated with the disinfectant full strength.

FOR ATTENDANTS ON THE SICK. — Empty the contents of this bottle into a pint of water, and wash the hands and other portions of the body, if soiled, with it, rinsing off with clean water. In sick rooms and hospital wards, wash all surfaces with the same solution.

☞This disinfectant, when mixed with water, as described, will not injure the hands, but should not get into the mouth.

As has been stated above, in view of the probability of a fresh invasion of cholera in 1893, the officers of the road determined to be as fully prepared for it as possible, and accordingly, in December,

1892, Mr. Theodore N. Ely, then Superintendent, now Chief, of Motive Power, desired me to make a careful series of tests to determine, in the most rigid manner, the precise germicidal value of their standard disinfectant, and to suggest to them, if I could, how its efficiency might be improved.

In view of the fact that the composition of the disinfectant is well known, that it is not for sale, except to its employees or where the interests of the road are directly involved, and is not in any sense a proprietary preparation and, above all, impressed with the importance of the inquiry to the public welfare, I consented to undertake the investigation, although with reluctance because of the peculiar difficulties involved in all efficiency tests upon germicides. I was fortunate, however, in securing throughout the investigation the aid of Mr. Albert P. Mathews, S.B., Assistant in Biology at the Massachusetts Institute of Technology, to whose skill and devotion the work owes much of whatever value it may possess.

In the present state of opinion regarding the active cause of infectious disease, which holds that this is invariably due to specific microörganisms, it becomes simple in theory to determine the value of any germicide or antiseptic. It seems, at first sight, easy enough to test the efficiency of a disinfectant by simply observing under various conditions its germicidal power. But in arranging the details of the experiments difficulties arise which are hard to overcome.

It might be supposed that if we exposed known numbers of specific disease germs to the action of a fixed amount of the disinfectant for a definite period, and then made cultures from the mixture, we should readily settle the efficiency of the disinfectant at the given strength. But this is by no means the case; for, unless great care be taken to prevent it, we may carry over with the test sample of the mixture taken for planting enough of the disinfectant to inhibit later the development of the still-living germs. Errors of this kind are particularly insidious and very difficult to avoid. Again, there is reason to believe that cultures of the germs submitted to examination vary in their endurance considerably, particularly if these are of kinds which produce spores. As in the higher plants some fields of corn or oats are strong and vigorous while others are weak and sickly, so here it is important to know that the cultures or crops of bacteria with which we are dealing are fairly representative of those which devastate the human body.

The problem in this case was strictly one of germicidal and not merely antiseptic properties. For the preservation of food the problem is often one of antisepsis, but into disinfection this milder problem does not enter. The question is one of destruction, not inhibition, and may be stated thus: How efficient is the disinfectant as a destroyer of the germs of infectious disease?

The methods used in the examinations of the germicidal power of disinfectants have been almost as numerous as the observers, and the results obtained have varied widely. Koch has employed a silk thread dipped into the culture and then exposed to the action of the disinfectant. The thread was afterwards washed with sterile distilled water, and then planted on the surface of the plated medium or else sown in bouillon. Such a method is open to serious objection, as it is difficult to wash away all the disinfectant clinging to the thread and the slight amount left may continue to act antiseptically, and lead to erroneous conclusions.

Sternberg, in this country, has proceeded in a different manner. He exposes the broken-down beef tea, or pure culture of the bacteria in bouillon, to a known strength of the germicide for a given length of time, after which he transfers by peculiar flasks a certain small amount to a large amount of fresh alkaline bouillon and allows incubation to proceed. The objection to this method is that he inevitably introduces into the second culture medium an uncertain small amount of the disinfectant. The methods of Koch and Sternberg are both, at least in theory, somewhat untrustworthy, for the reason that the action of the germicide cannot be checked at once and because each introduces into his control medium some of the germicide.

It is self-evident that in testing any germicide it is necessary to stop its action quickly or to remove it wholly from the test medium. Only when we accomplish this can we hope to be sure of the results.

In solving the present problem we were guided by the work of those experimenters who had also recognized the necessity of freeing the bacteria after their exposure for the given time from the possible antiseptic influences of small amounts of the germicide thus carried over. Two reagents have hitherto been used for this purpose for antiseptics containing corrosive sublimate, namely, ammonium sulphide and hydrogen sulphide. Our problem, however, was not so simple. In the first place, it was not only necessary to test the antiseptic effect of the precipitant upon every specific germ to assure ourselves

that it was not itself more or less antiseptic; but in the second place, we were here not merely working with a dilute solution of the sublimate, but also with a strong solution of zincic and cupric chlorides, and if either of the precipitants mentioned were used there would be formed a heavy, flocculent precipitate likely to gather around the germs and drag them down, thus leading to serious error. Hence we were compelled to run control experiments with pure water in many cases, and sometimes with other precipitants, while at the same time carefully testing the antiseptic action of the precipitant itself.

As already stated, we endeavored to eliminate the various sources of error that had hitherto been recognized. The first question was that of the cultures themselves, and only the freshest cultures of pathogenic germs were used, since it is probable that such cultures are most nearly normal. We also satisfied ourselves that each culture was in a vigorous state, as indicated by the rapidity of its growth or the manner in which it formed spores.

The cultures of the specific bacteria used were subjected to rigid differential tests in order to establish the fact that they were really the germs in question. The culture of typhoid fever bacilli had been isolated not long before from the spleen of a woman dead of typhoid fever. The culture of anthrax was comparatively fresh, having been obtained from a patient in the Boston City Hospital. The culture of *Staphylococcus pyogenes aureus* was derived from one isolated a few days previous by Dr. W. T. Councilman, Pathologist to the Boston City Hospital. The culture of the *Streptococcus* of diphtheria was also derived from one isolated by Dr. Councilman a few days before it was used in these experiments. The culture of the cholera *Spirillum* of Koch was derived from one isolated by Dr. Dunham, of New York, from a case of Asiatic cholera there in September last. The culture of *Bacillus subtilis* had been in the laboratory for some time, but, as was proved by the resistant properties of its spores when subjected to heat, it was in a most vigorous condition. We may then safely conclude that the cultures employed in the tests were in a fresh and vigorous condition.

It is generally believed that mercury forms a more or less stable compound with albumen, though whether this compound is or is not soluble, and whether it is or is not effective in making the germicide powerful, is a matter of dispute. Vaughan contends that it is very poisonous, while others hold that such an envelope forming about the

bodies of the bacteria protects them from the further action of the germicide. How far these ideas are true, or how far they are important if true, is uncertain.

In the actual investigations we introduced a known amount of the fluid holding the germs in suspension into a known amount of the disinfectant, and at the end of a given interval transferred a small known amount of this mixture to a large amount of dilute ammonium sulphide which was used as the inhibitor, sometimes making control experiments with stannous chloride and at other times with water in the place of the ammonium sulphide. We used ammonium sulphide in preference to hydrogen sulphide as inhibitor, for the reason that the solution of the germicide was found to be decidedly acid, and thus we were forced to neutralize the acid at the same time that the mercury was neutralized. The use of any sulphide we adopted with hesitation, owing to the formation of a heavy flocculent precipitate; but by making control tests with stannous chloride, which simply neutralized the mercury and did not affect the other chlorides, and by using water in the place of the sulphide, we came to the conclusion that, in spite of this danger, the ammonium sulphide was the best inhibitor we could use, although it may be that further experiment would show the stannous chloride to be equally valuable.

We thus succeeded in stopping the action of the disinfectant upon its arrival in the second flask, and by employing large dilutions further reduced the possibility of the contamination of the culture medium with an antiseptic salt. It will be noticed, also, in examining the detailed history of the experiments, that through planting a control from the second flask *directly* into a large amount of bouillon we checked our final results and escaped the danger of losing the germs through too great dilutions.

In all experiments controls were made into bouillon to determine the initial sterility of the dilution flask; a sample was also planted from the precipitating flask to make sure that the bacteria were not lost in passing from the precipitating or inhibition flask to the third or dilution flask; and finally, controls were made to discover how many bacteria would have appeared in a cubic centimeter of the third flask had the disinfectant been water. We have thus had a constant check on all results, and feel confident that error has as far as possible been eliminated.

In order, however, to guard against all possible error, when the end

of the experiment was reached and the limit of the resistance of the bacterium had been determined by means of the precipitation methods, two other methods were used in order to check the results. One of these was that recommended by Sternberg, namely, exposing the culture to the germicide for a certain length of time and then transferring a small quantity of the mixture — as much as would cling to a platinum needle — into a flask of bouillon and allowing the latter to grow at optimum temperature. The other method was to transfer a platinum loopful of the mixed liquid culture and germicide to a weak solution of ammonium sulphide and then pour the whole of this into a large flask of bouillon. In the latter method we escaped both the difficulty of introducing the corrosive sublimate into the culture and the danger of great dilutions.

The precise method of procedure[1] was this: Bouillon cultures of the species to be tested were grown for two days in the incubator at 37.5°C. Two cubic centimeters of such a culture, after prolonged shaking, and after microscopical and macroscopical examination had determined that it was in good condition, were transferred to a 60 cc. sterile Erlenmeyer flask, and to them 13 cc. of sterile distilled water were added. An equal volume, or 15 cc., of the germicide was next added, and the time of exposure was determined by means of a stop watch. The flask here used may be called the *action flask*, and the time of exposure the *action period*. Towards the end of the action period one cubic centimeter was rapidly transferred to 500 cc. of dilute solution of ammonium sulphide, or stannous chloride, and well shaken for thirty seconds, the precipitate not being allowed to settle. At the end of the thirty seconds one cubic centimeter from this flask, which may be called the *inhibition flask*, was transferred to a flask containing 250 cc. of sterile distilled water; the last flask may be called the *dilution flask*. Immediately after this two flasks, containing each 25 cc. of bouillon, were planted, each with .3 cc., from the inhibition flask. This was done in order to have a dilution control. At the end of a couple of minutes two or three tubes of melted agar were sown with one cubic centimeter each from the mixture in the third or dilution flask, and immediately plated. All plates and flasks were then placed in the incubator at 37.5°C.

Immediately preceding the experiment one cubic centimeter of

[1] In formulating a definite mode of procedure we were guided, in part, by experiments made in this laboratory upon peroxide of hydrogen by the late George V. McLauthlin.

water from the dilution flask was planted in bouillon in order to determine its sterility. This precaution was found to be necessary when working with the spores of *B. subtilis* and *B. anthracis*, both of which proved to be very resistant to ordinary sterilization methods.

Immediately following each series of experiments a control experiment was made as follows: Two cubic centimeters of the bouillon culture used in testing were diluted with 28 cc. of water, and one cubic centimeter of this diluted culture carried into 500 cc. of ammonium sulphide in the inhibition flask. After thirty seconds one cubic centimeter from the mixture in the inhibition flask was carried to the dilution flask, containing 250 cc. of sterile water, and from the last flask agar plates were made by sowing in each tube of melted agar one cubic centimeter of the liquid and then plating the mass. Two other controls were obtained for each species by substituting for ammonium sulphide in the inhibition flask stannous chloride in the one case and distilled water in the other, and making the dilutions the same as in the principal testing experiments.

This routine was repeated for the different action periods until it was found that the germs were killed. When this knowledge had been obtained still another control was employed, namely, Sternberg's method and the modification of it already described.

It will thus appear that all results obtained were carefully checked, and all tests finally made in duplicate or triplicate. After the actual theoretical value of the germicide had been thus established, its actual value in practice was proved by its action on a typhoid fever stool.

## A DETAILED ACCOUNT OF THE EXPERIMENTS MADE TO DETERMINE THE GERMICIDAL EFFICIENCY OF THE DISINFECTANT.

### *A. Experiments upon the Typhoid Fever Bacillus of Eberth.*

Inasmuch as the tests with this bacillus were the first undertaken, it was necessary to develop the methods to be used in testing. The first few experiments were therefore intended to determine whether the stannous chloride or the ammonium sulphide were objectionable because of being germicides in themselves, and whether either method was superior to that of simple dilution in water.

Experiment 1, when compared with Experiment 2, indicated that the method of inhibition by precipitating with stannous chloride, was superior to that of diluting with water. Experiment 1, in which the

chloride was used, indicated that the germs were still alive after one minute's exposure, while Experiment 2 showed that all had been killed. If, then, we had relied upon the method of simple dilution we should have been led into error at the start.

EXPERIMENT 1.

1 volume of disinfectant diluted with 3 volumes of water.

1 cc. of 50-days-old bouillon culture of Eberth bacilli introduced into 250 cc. of this diluted disinfectant and exposed for one minute.

1 cc. of the mixture of disinfectant and culture then carried to 500 cc. of dilute, weakly acid stannous chloride, and left for 35 seconds.

1 cc. of liquid from the stannous chloride flask then mixed with 500 cc. of water and well shaken.

From the last flask five agar plates were planted with one cc. each.

Result: Average number of colonies per cc. of last flask, 3.

EXPERIMENT 2.

Same conditions as in preceding experiment. Disinfectant same strength and in same amount, and the same amount of the same culture used.

Exposure to the disinfectant, one minute.

1 cc. of mixture of culture and disinfectant then carried to 500 cc. of sterile water and well shaken for 35 seconds.

1 cc. of this fluid then carried to 500 cc. of sterile water.

Five agar plates were planted with 1 cc. of the last flask.

Result: All the plates were sterile.

These experiments having indicated the value of the stannous chloride as an inhibitor, we next proceeded to determine that of the ammonium sulphide.

EXPERIMENT 3.

2½-days-old bouillon culture of Eberth bacilli. Grown at 37.5°C.

1 cc. of this culture carried to 250 cc. of disinfectant diluted as in 1 and 2. Exposed 20 seconds.

1 cc. of the disinfectant and culture then mixed wtth 500 cc. of ammonium sulphide. Exposed for 20 seconds.

1 cc. of this mixture from Flask 2 well washed in 500 cc. of sterile water.

Five agar plates were then made from the last flask, each plate containing 1 cc.

Result: Three plates were sterile; two had one colony each upon them.

In order to determine whether a longer exposure to the ammonium sulphide would injure the bacteria we allowed the inhibition flask to stand for three minutes, when we again diluted one cubic centimeter of it with 500 cc. of sterile water, and after shaking planted five cubic centimeters of the last dilution in five tubes of agar.

Result: Two of the plates had one colony each; one of them contained three; and the third was sterile.

This indicated that the sulphide possessed a very slight action upon the bacteria, if it exerted any at all. The slightly greater numbers of bacteria grown on these plates were wholly within the

range of variation in exactly similar series of experiments. Otherwise they would seem to indicate that a longer exposure of the bacteria to the sulphide was advantageous.

The next experiment was made to test the value of washing the disinfectant from the bacteria by water.

EXPERIMENT 4.

Same conditions and culture as in Experiment 3, but the exposure was for 18 seconds.

1 cc. of mixture of disinfectant and culture was well shaken in 500 cc. of sterile water for 20 seconds, Flask 2.

1 cc. from Flask 2 then shaken in 500 cc. of sterile water, Flask 3.

Six agar plates were planted with 1 cc. each from Flask 3.

Result: three plates sterile; two plates had one colony each upon them.

The result of this experiment would seem to indicate that simple dilution was as effective as ammonium sulphide precipitation. Further experiment proved that this conclusion was erroneous. Experiment 5 is the control for the two preceding, made in order to determine whether the bacteria had been lost by too great dilution.

EXPERIMENT 5.

1 cc. of same culture as in Experiment 4 diluted with sterile water to the same degree that it would have been diluted had it passed through the action, inhibition, and dilution flasks. No disinfectant used.

Six agar plates planted with 1 cc. each of Flask 3.

Result: These plates had an average of eleven colonies each upon them.

The result of Experiment 5 was sufficient to convince us that the dilution of the disinfectant was too great; and thereafter, with the exception of the next control experiment, we reduced the last flask to 250 cc.; reduced the disinfectant volume to 15 cc.; and employed two cc. of the culture in the place of one.

EXPERIMENT 6.

This was made to test the germicidal power of the stannous chloride.

1 cc. of culture was carried to 250 cc. of sterile water.

1 cc. of this mixture then planted in 500 cc. of dilute stannous chloride and left for 20 seconds.

1 cc. of this then carried to 500 cc. of sterile water.

Six agar plates were planted each with 1 cc. of last flask.

Result: There was an average number of 14 colonies upon each plate.

This result proved that the stannous chloride in the length of time the bacteria was exposed to it, and in the strength in which it was used, exerted no appreciable deleterious effect upon the typhoid bacilli.

Having now made a test of methods, in which it appeared that there was little advantage in using stannous chloride in preference to ammonium sulphide as inhibitor, we proceeded to determine the efficiency of the disinfectant. For this purpose we employed the disinfectant diluted to twice its normal bulk. This dilution was secured in the early experiments by means of the culture fluid itself. Later, however, we diluted with water. This strength of the disinfectant was adopted as the standard both because it seemed likely that such a strength would be the one employed in practice and because we were thereby enabled to compare its efficiency with that of neutral solutions of mercuric chloride of the strength 1 : 1,000 as determined by many experimenters.

EXPERIMENT 7.

Fifteen cc. of a two-days culture in bouillon of Eberth bacilli were mixed with 15 cc. of disinfectant full strength. Thus the culture acted as the diluter of the disinfectant. The exposure was for 25 seconds.

1 cc. of the mixture was then carried to 500 cc. of stannous chloride and shaken for 20 seconds.

1 cc. from this flask was then transferred to Flask 3, containing 250 cc. of sterile water.

Five agar plates were then planted from the last flask with one cc. each.

Result: All the plates were sterile.

EXPERIMENT 8.

Identical with the preceding, except that the culture was exposed to the disinfectant for 45 seconds.

Five agar plates planted from the last flask.

Result: All plates sterile.

EXPERIMENT 9.

Control of 7 and 8.

$\frac{1}{2}$ cc. of culture transferred to 500 cc. of stannous chloride for 20 seconds.

1 cc. of this fluid then diluted with 250 cc. of sterile water.

Two agar plates planted with 1 cc. each from the last flask.

Result: 2,035 colonies upon each plate.

It was obvious from the preceding experiments that twenty-five seconds' exposure sufficed to kill the bacteria. We now determined the minimum length of time of exposure necessary to accomplish this result. Here we adopted a slightly different method of pro-

cedure. It will be observed that the disinfectant was diluted in these cases with the culture medium itself. Considering that this medium was of an albuminous nature and therefore likely to introduce an element of uncertainty into the results, as the exact solubility of the albuminate of mercury is a matter of dispute, and its effect upon the germicidal value of mercuric salts has also been questioned, we freed the bacteria from this albuminous envelope as far as possible by thoroughly shaking two cubic centimeters of the culture in sterile water sufficient to dilute the disinfectant to twice its bulk. Hereafter, then, it will be understood that the 15 cc. of disinfectant were diluted with 13 cc. of water and 2 cc. of culture medium. In this way the bacteria themselves were exposed more directly to the action of the germicide.

EXPERIMENT 10.

Fifteen cc. of disinfectant mixed with 13 cc. of water and 2 cc. of culture of typhoid bacilli. Exposure of 10 seconds.

1 cc. of mixture carried to 500 cc. of stannous chloride for 20 seconds.

1 cc. from this flask, known as the inhibition flask, next transferred to a dilution flask containing 250 cc. of sterile water.

Two bouillon flasks containing 25 cc. each of bouillon were then sown with 0.2 cc. each from the inhibition flask (No. 2).

Two agar plates were made from Flask 3.

Result: One bouillon flask sterile; other bouillon flask growth. Agar plates, two sterile; the third contained two colonies.

EXPERIMENT 11.

Identical with 10, except that the exposure to the disinfectant was for 15 seconds.
Agar plates and bouillon flasks planted as in the preceding experiment.
Result: both plates sterile. Both bouillon flasks sterile.

EXPERIMENT 12.

Identical with 10, except that the exposure to the disinfectant was for 20 seconds.
Agar plates and bouillon flasks planted as in 10.
Result: Agar plates were sterile. Bouillon flasks were sterile.

From these experiments it follows that the Eberth bacillus of typhoid fever is killed by an exposure to the disinfectant — the latter being diluted to one half its original strength — of about twelve seconds. It is not killed in ten seconds, but it is in fifteen. We now proceeded to control this result by inhibition with ammonium sulphide in the place of the stannous chloride.

EXPERIMENT 13.

Identical with 11, except that ammonium sulphide was placed in the middle flask in place of the stannous chloride. The culture was the same and the dilutions were to the same amount and of the same kind.

Exposure of culture to the disinfectant for 15 seconds. Carried to the sulphide and exposed for 30 seconds.

Agar plates made from Flask 3, and bouillon flasks from Flask 2.

Result: Agar plates sterile. Bouillon flasks remained sterile.

EXPERIMENT 14.

This experiment the same in all respects as 13, except that the exposure to the disinfectant was for 10 seconds only.

Result: Bouillon flasks sterile; agar plates sterile.

It will be seen that the inhibition with ammonium sulphide confirmed the results of inhibition with stannous chloride. The only difference was that the latter method showed some of the bacteria to be still alive after ten seconds' exposure to the disinfectant, while the former indicated that all had been killed. It may have been that in the former case the exposure was for a second or two longer than in the latter, as it was impossible to work with an accuracy within a second.

The control experiments for the above, to guard that the bacteria should not be lost from too great dilution, showed the last flask to contain 150 colonies to the cubic centimeter, and proved the dilutions to be safe. We also made another control, to determine that the stannous choride was harmless. The plates showed an average of 104 colonies to the cubic centimeter — a result within the range of unavoidable differences in the number of bacteria transferred from flask to flask.

The result was then tested by Sternberg's method as follows:

1 cc. of culture was introduced into 1 cc. of disinfectant. At the end of 10 seconds a little of the mixture was carried on a platinum needle and mixed with 25 cc. of bouillon. The flask remained sterile after being in the incubator for three days. At the end of 15 seconds another flask was sown in the same manner. This flask also remained sterile.

A further confirmation was secured in the following way:

1 cc. of culture was introduced into 1 cc. of disinfectant. At the end of 10 seconds a platinum loop of the mixture was mixed with 1 cc. of dilute ammonium sulphide, and after 30 seconds here the mixture was poured into a flask of bouillon containing 25 cc. The bouillon flask at the end of 24 hours contained a fine crop of typhoid bacilli. At the end of 15 seconds exposure to the disinfectant a second platinum loop of the mixture was precipitated in the same manner and sown in bouillon. This flask remained sterile.

Conclusion: The typhoid fever bacillus of Eberth is killed by an exposure of 15 seconds to the disinfectant when the latter is diluted to twice its bulk.

## *B. Experiments upon Spores of Bacillus Subtilis.*

In all experiments upon *Bacillus subtilis* we employed a bouillon culture grown for three days at 37.5° C. and microscopically determined to be in the spore state.

EXPERIMENT 15.

2 cc. of culture of *B. subtilis* mixed well with 13 cc. of sterile water. 15 cc. of disinfectant then poured into this. Shaken well for 5 minutes.

1 cc. carried to 500 cc. of ammonium sulphide. Left here for 30 seconds. 1 cc. from Flask 2 then carried to Flask 3, containing 250 cc. of sterile water.

Bouillon flasks were sown from Flask 2, and agar plates from Flask 3.

Result: Growth in bouillon flasks. Agar plates contained an average of 5 colonies.

EXPERIMENT 16.

Identical with Experiment 15, except that stannous chloride was employed as inhibitor. Exposure to disinfectant of 5 minutes. Bouillon flasks and agar plates as usual.

Result: Growth in bouillon flasks. Agar plates had an average of 7 colonies each.

EXPERIMENT 17.

Identical with 15. Ammonium sulphide, inhibitor. Exposure of 7 minutes to disinfectant. Agar plates from Flask 3, bouillon flasks from Flask 2.

Result: Bouillon showed a copious growth. Agar plates an average of 8 colonies.

EXPERIMENT 18.

Same culture as preceding. Stannous chloride, inhibitor. Exposure to disinfectant for 7 minutes.

Result: Growth in bouillon flasks. Agar plates an average of 6 colonies.

EXPERIMENT 19.

Identical with 17, except that exposure was for 10 minutes. Ammonium sulphide, inhibitor.

Result: Growth in bouillon flasks. Agar plates an average of 3 colonies.

EXPERIMENT 20.

Identical with 18, except exposure of 10 minutes. Stannous chloride, inhibitor.

Result: Growth in bouillon flasks. Agar plates an average of 3 colonies.

EXPERIMENT 21.

Control for experiments from 15–20.

2 cc. of culture. 28 cc. of water.

1 cc. of this then diluted with 500 cc. Ammonium sulphide.

1 cc. of mixture then carried to 250 cc. water.

Result: Agar plates showed an average of 12 colonies.

EXPERIMENT 22.

Identical with 17. Exposure for 12½ minutes. Inhibitor, ammonium sulphide

Result: Growth in bouillon flasks. Agar plates sterile.

EXPERIMENT 23.

Same as preceding. Exposure of 15 minutes. Inhibitor, ammonium sulphide.
Result: Bouillon flasks sterile. Agar plates sterile.

EXPERIMENT 24.

Control for 22 and 23.
2 cc. culture. 28 cc. water.
1 cc. of mixture carried to 500 cc. Ammonium sulphide.
1 cc. of this to 250 cc. water.
Result: Agar plates an average of 44 colonies.

It having appeared from the above that *B. subtilis* spores are destroyed in fifteen minutes the result was confirmed by Sternberg's method. The results were as follows:

Flask 1. Exposed 15 minutes showed a growth.
Flask 2. Exposed 17 minutes remained sterile.

We also employed the modification of this method already noticed. The results of this were as follows:

Flask 1. Exposed 15½ minutes and inhibited with ammonium sulphide. Growth.
Flask 2. Exposed 17½ minutes and inhibited with ammonium sulphide. Growth.
Flask 3. Exposed 20 minutes and inhibited with ammonium sulphide. Sterile.
Conclusion: *Bacillus subtilis* spores are, under certain conditions, killed by the germicide diluted to twice its bulk in 20 minutes. Under other conditions they appear to be killed in 17 minutes.

### *C. Experiments upon the Streptococcus of pseudo-Diphtheria.*

This *Streptococcus* has been repeatedly isolated from the membrane in the throats of patients sick with scarlet fever, and others erroneously supposed to have true diphtheria. It apparently bears an ætiological significance in the cases of such membranous inflammations of the throat. It has already been established at this laboratory that this *Streptococcus*, believed by some to be identical with *Streptococcus pyogenes*, is even more resistant to germicides than the bacillus of true diphtheria, *i.e.*, the bacillus of Klebs-Löffler.

EXPERIMENT 25.

2 cc. culture, 13 cc. water, and 15 cc. of disinfectant, mixed for 10 seconds.
1 cc. of the mixture then mixed with 500 cc. of ammonium sulphide for 30 seconds.
1 cc. of this mixture transferred to Flask 3, containing 250 cc. water. Bouillon flasks planted from Flask 2. Agar plates with 1 cc. each from Flask 3.
Result: Agar plates sterile. Bouillon showed a growth.

EXPERIMENT 26.

Same as 25, except the exposure of 12 seconds. Ammonium sulphide.
Result: Agar plates sterile; bouillon flasks sterile.

EXPERIMENT 27.

Control of 25 and 26.
2 cc. of culture mixed with 28 cc. of water.
1 cc. of mixture to 500 cc. of ammonium sulphide for 30 seconds.
1 cc. of sulphide flask then transferred to 250 cc. of water.
Agar plates from Flask 3.
Result: Plates showed an average of 39 colonies.

From the above it appeared certain that an exposure for twelve seconds to the disinfectant when the latter is diluted to twice its volume is sufficient to kill the *Streptococcus diphtheriæ.*

This result was confirmed by Sternberg's method and the modification thereof employed in the case of *B. subtilis* and the Eberth bacillus.

### *D. Experiments upon Staphylococcus pyogenes aureus.*

The culture for these experiments came originally from the laboratory of Dr. Councilman. Three-days-old bouillon cultures were used.

EXPERIMENT 28.

2 cc. bouillon culture, 13 cc. water, and 15 cc. disinfectant. Exposed 10 seconds.
1 cc. of mixture then carried to Flask 2, containing 500 cc. Ammonium sulphide. Exposed here for 30 seconds.
1 cc. then transferred from Flask 2 to Flask 3, containing 250 cc. sterile water.
Bouillon flasks containing 25 cc. bouillon were planted with .2 cc. of mixture from Flask 2. Agar plates with 1 cc. each from Flask 3.
Result: Agar plates sterile. Bouillon flasks sterile.

EXPERIMENT 29.

Same as above, but exposed to disinfectant for 20 seconds. Ammonium sulphide as inhibitor.
Result: Agar plates sterile. Bouillon flasks sterile.

EXPERIMENT 30.

Control for 28 and 29.
2 cc. culture mixed with 28 cc. water.
1 cc. then to 500 cc. ammonium sulphide.
1 cc. of this then diluted 250 times with water.
Result: Agar plates from last flask showed 530 colonies each.

The conclusion from these experiments is that *Staphylococcus pyogenes aureus* is killed by a ten seconds' exposure to the germicide when the latter is diluted to twice its bulk.

This result was confirmed by Sternberg's method and the modification of it already described. In each case the flasks of ten seconds remained sterile, as did also those exposed for twelve and a half seconds.

### *E. Experiments upon the Spirillum of Asiatic Cholera.*

For these experiments we used a bouillon culture grown for four days at 37.5° C. The culture came originally from Dr. Dunham's laboratory.

EXPERIMENT 31.

2 cc. of culture, 15 cc. of disinfectant, and 13 cc. of sterile water were mixed for 10 seconds.
1 cc. of mixture precipitated in 500 cc. Ammonium sulphide. 30 seconds.
1 cc. of this flask then carried to 250 cc. of sterile water.
Bouillon flasks were planted from Flask 2. Agar plates from Flask 3.
Results: Agar plates sterile. Flasks sterile.

EXPERIMENT 32.

Same as 31, except the exposure to the disinfectant was for 15 seconds.
Result: Agar plates sterile. Bouillon flasks sterile.

EXPERIMENT 33.

Control for 31 and 32.
2 cc. of culture diluted with 28 cc. water, then 1 cc. passed through same amounts of ammonium sulphide and water as usual.
Agar plates were planted from Flask 3.
Result: Agar plates showed an average of 5 colonies to a cubic centimeter of liquid from last flask.

The dilutions here were evidently a little too great, but when it is remembered that on this basis the middle flask should contain 1,250 cholera bacilli to the cubic centimeter, if they had not been killed, we considered the fact of the sterility of the flasks of bouillon planted from this flask as evidence enough that the bacteria were killed by the exposure given them.

The experiments upon the *Spirillum* of Asiatic cholera would indicate that this bacterium is killed by an exposure to the germicide diluted to twice its volume for the space of ten seconds.

This result was confirmed by Sternberg's method and the modification of it described. Bouillon flasks at 10 seconds remained sterile.

### *F. Experiments upon Spores of Bacillus anthracis.*

The culture of *Bacillus anthracis* used in these tests was from a luxuriant culture isolated by Prof. G. R. Tucker from a patient in the Boston City Hospital about one year before. A three-days' bouillon culture was used.

EXPERIMENT 34.

2 cc. of culture well shaken in 13 cc. of water; 15 cc. of disinfectant mixed with it for 15 minutes.

1 cc. of the mixture was then inhibited by 500 cc. of ammonium sulphide.

1 cc. from the last flask was, at the end of 30 seconds, carried to Flask 3, containing 250 cc. of distilled water.

Agar plates made from the last flask. Bouillon flasks planted from the inhibition flask.

Result: Agar plates had an average of 3 colonies each. Bouillon flasks showed copious growth.

EXPERIMENT 35.

Control for 34.

2 cc. of culture mixed with 28 cc. of water.

1 cc. of mixture then transferred to 500 cc. of ammonium sulphide for 30 seconds.

1 cc. of mixture then diluted in 250 cc. of sterile water.

Agar plates from last flask.

Result: Plates contained an average of 52 colonies each.

We next passed on to determine the vitality of the spores and found them exceedingly resistant to heat.

EXPERIMENT 36.

1 cc. of the culture used in the preceding two experiments was placed in a sterile test tube and immersed in boiling water. Every two minutes a sterile platinum needle was plunged into the hot culture and then mixed with 6 cc. of sterile bouillon. In order to determine the exact degree of heat to which the spores were exposed we placed next to the tube containing the culture a second tube containing 1 cc. of sterile water, and within this tube suspended a thermometer so that it was at every point separated from the glass of the tube. This thermometer registered as follows: 5 seconds, 60 degrees C.; 10 seconds, 70 degrees; 15 seconds, 80 degrees; 30 seconds, 92 degrees; 45 seconds, 95 degrees; 60 seconds, 97 degrees; 70 seconds, 99 degrees. It remained at this temperature during the course of the tests.

The result proved that some of the spores were still alive at eleven minutes after immersion. We made no test later than that time.

Experiment 34 indicated that nearly all the spores were killed after fifteen minutes' exposure to the disinfectant.

EXPERIMENT 37.

Identical with 34, except that the exposure was for 20 minutes.

Result: Agar plates sterile. Bouillon flasks sterile.

Having now ascertained that anthrax spores of a very resistant type are killed by the disinfectant in twenty minutes, we confirmed the result as usual, by Sternberg's method, and also by the modification of that method already described.

It will be remembered that in the modification of the method we precipitated a platinum loopful of the mixture of culture and disinfectant in ammonium sulphide before pouring the whole mixture into bouillon.

Result:

| | | | | | |
|---|---|---|---|---|---|
| 1½ minutes . . . | Direct. | Growth. | 14 minutes . . . | Direct. | Growth. |
| 3 minutes . . . | Direct. | Growth. | 17 minutes . . . | Precipitated. | Growth. |
| 5 minutes . . . | Direct. | Growth. | 19 minutes . . . | Direct. | Sterile. |
| 8 minutes . . . | Precipitated. | Growth. | 17½ minutes . . . | Precipitated. | Growth. |
| 10 minutes . . . | Direct. | Growth. | 19 minutes . . . | Precipitated. | Sterile. |
| 12 minutes . . . | Precipitated. | Growth. | | | |

From this result we may conclude that anthrax spores of this high degree of resistance are killed by an exposure to the disinfectant of nineteen minutes, the disinfectant being diluted to twice its volume.

### *G. A Practical Test of the Disinfectant.*

In order to test the working of the disinfectant in actual use we mixed a stool of a typhoid patient with an equal amount of disinfectant. The stool was diarrhœic, but contained many hard lumps of fæces. The mixture was shaken three or four times during the test. In order to determine at what time the stool became sterile we transferred a small portion upon a platinum loop at the end of thirty seconds, and for every minute's interval thereafter up to twenty minutes, to a tube of melted agar containing perhaps 6 cc. of agar. At the end of twenty-four hours the plates planted at thirty seconds' exposure proved to be well spotted with colonies of bacteria, but far less than the control made at the beginning. From this time on they rapidly diminished until at the end of three minutes and a half there were none apparent, nor did any appear upon the subsequent plates or in the bouillon flasks. The efficiency of the disinfectant with fæcal bacteria was thus established.

SUMMARY OF EXPERIMENTS ON *B. TYPHI ABDOMINALIS.*

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 1. | 50 days | $\frac{1}{4}$ | 1 minute | $SnCl_2$ | 3 | . . . | . . . |
| 2. | 50 " | $\frac{1}{4}$ | 1 " | $H_2O$ | 0 | . . . | . . . |
| 3. | $2\frac{1}{2}$ " | $\frac{1}{4}$ | 20 seconds | $(NH_4)_2S$ | 0 and 1 | . . . | 11 |
| 4. | $2\frac{1}{2}$ " | $\frac{1}{4}$ | 18 " | $H_2O$ | 0 and 1 | . . . | 11 |
| 5. | $2\frac{1}{2}$ " | . . . | not exposed | $SnCl_2$ | 11 | . . . | . . . |
| 7. | 2 " | $\frac{1}{2}$ | 25 seconds | $SnCl_2$ | 0 | . . . | 2035 |
| 8. | 2 " | $\frac{1}{2}$ | 45 " | $SnCl_2$ | 0 | . . . | 2035 |
| 10. | 2 " | $\frac{1}{2}$ | 10 " | $SnCl_2$ | 0 and 2 | growth. | 150 |
| 11. | 2 " | $\frac{1}{2}$ | 15 " | $SnCl_2$ | 0 | sterile. | 150 |
| 12. | 2 " | $\frac{1}{2}$ | 20 " | $SnCl_2$ | 0 | " | 150 |
| 13. | 2 " | $\frac{1}{2}$ | 15 " | $(NH_4)_2S$ | 0 | " | 150 |
| 14. | 2 " | $\frac{1}{2}$ | 10 " | $(NH_4)_2S$ | 0 | " | 150 |

Control: Sternberg's Method, Flask at 10 seconds, sterile.

Control: Modification of Sternberg's Method, Flask at 10 seconds, growth; 15 seconds, sterile.

SUMMARY OF EXPERIMENTS ON SPORES OF *BACILLUS SUBTILIS.*

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 15. | 3 days | $\frac{1}{2}$ | 5 minutes | $(NH_4)_2S$ | 5 | growth | 12 |
| 16. | 3 " | $\frac{1}{2}$ | 5 " | $SnCl_2$ | 7 | " | 12 |
| 17. | 3 " | $\frac{1}{2}$ | 7 " | $(NH_4)_2S$ | 8 | " | 12 |
| 18. | 3 " | $\frac{1}{2}$ | 7 " | $SnCl_2$ | 6 | " | 12 |
| 19. | 3 " | $\frac{1}{2}$ | 10 " | $(NH_4)_2S$ | 3 | " | 12 |
| 20. | 3 " | $\frac{1}{2}$ | 10 " | $SnCl_2$ | 3 | " | 12 |
| 22. | 3 " | $\frac{1}{2}$ | $12\frac{1}{2}$ " | $(NH_4)_2S$ | 0 | " | 44 |
| 23. | 3 " | $\frac{1}{2}$ | 15 " | $(NH_4)_2S$ | 0 | sterile | 44 |

Control: Sternberg's Method, Flask at 15 minutes, growth; 17 minutes, growth.

Control: Sternberg's Method, modified, Flask at 15 minutes, growth; 17 minutes, growth; 20 minutes, sterile.

SUMMARY OF EXPERIMENTS ON *STREPTOCOCCUS DIPHTHERIÆ.*

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 25. | 3 days | ½ | 10 seconds | $(NH_4)_2S$ | 0 | growth | 39 |
| 26. | 3 " | ½ | 12 " | $(NH_4)_2S$ | 0 | sterile | 39 |

Control: Sternberg's Method, Flask at 10 seconds, growth; 12 seconds, sterile.
Control: Sternberg's Method, modified, Flask at 10 seconds, growth; 12 seconds, sterile.

SUMMARY OF EXPERIMENTS ON *S. PYOGENES AUREUS.*

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 28. | 3 days | ½ | 10 seconds | $(NH_4)_2S$ | 0 | sterile | 530 |
| 29. | 3 " | ½ | 20 " | $(NH_4)_2S$ | 0 | sterile | 530 |

Control: Sternberg's Method, Flask at 10 seconds, sterile; at 12 seconds, sterile.
Control: Sternberg's Method, modified, Flask at 10 seconds, sterile; at 12 seconds, sterile.

SUMMARY OF EXPERIMENTS ON SPIRILLUM OF ASIATIC CHOLERA.

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 31. | 4 days | ½ | 10 seconds | $(NH_4)_2S$ | 0 | sterile | 5 |
| 32. | 4 " | ½ | 15 " | $(NH_4)_2S$ | 0 | sterile | 5 |

Control: Sternberg's Method, 10 seconds flask, sterile.
Control: Sternberg's Method, modified, 10 seconds flask, sterile.

SUMMARY OF EXPERIMENTS ON SPORES OF *BACILLUS ANTHRACIS.*

| No. of the Experiment. | Age of Culture. | Strength of Disinfectant. | Time of Exposure to Disinfectant. | Precipitant used as Inhibitor. | Colonies on Agar Plates. | Bouillon Flasks. | Number of Colonies on Control. |
|---|---|---|---|---|---|---|---|
| 34. | 3 days | ½ | 15 minutes | $(NH_4)_2S$ | 3 | growth | 52 |
| 37. | 3 " | ½ | 20 " | $(NH_4)_2S$ | 0 | sterile | 52 |

Control: Sternberg's Method, Flask at 19 minutes, sterile.
Control: Sternberg's Method, modified, Flask at 17 minutes, growth; 19 minutes, sterile.

## CONCLUSIONS.

The foregoing experiments appear to establish the fact that the Standard Disinfectant used by the Pennsylvania Railroad Company will, under favorable circumstances, destroy the germs of typhoid fever, diphtheria, Asiatic cholera, and *Staphylococcus pyogenes aureus* in a few seconds, and the spores of *Bacillus subtilis* and *Bacillus anthracis* in a few minutes. It must, therefore, be regarded as satisfactory and of excellent efficiency.

There is no evidence that the zinc chloride materially contributes to its value as a disinfectant, and however great the value of zinc chloride as a deodorant may be, it is probable that if a portion, or all of this, could be replaced by a still more concentrated solution of corrosive sublimate the disinfectant might be improved. The recent paper of Green (*Zeit. für Hygiene*, etc., **13**, 511) suggests that the copper chloride also has some value. Finally, the decidedly acid reaction of the disinfectant as received is, from the germicidal point of view, an advantage.

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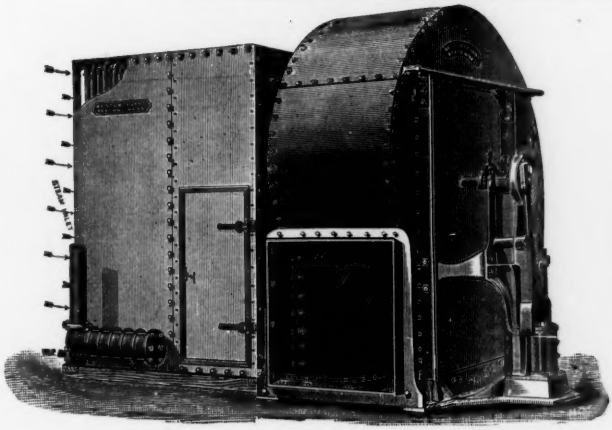

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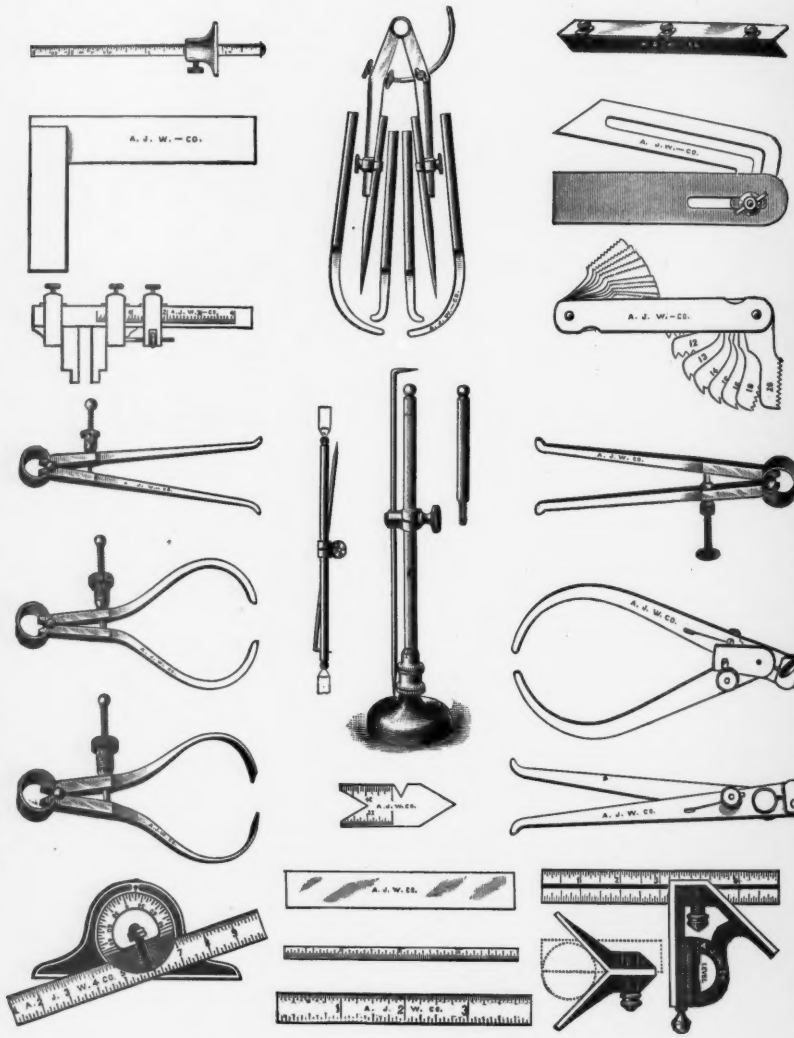

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